FARMERS' BULL... 1260

Rev.ed. follows

STORED-GRAIN PESTS

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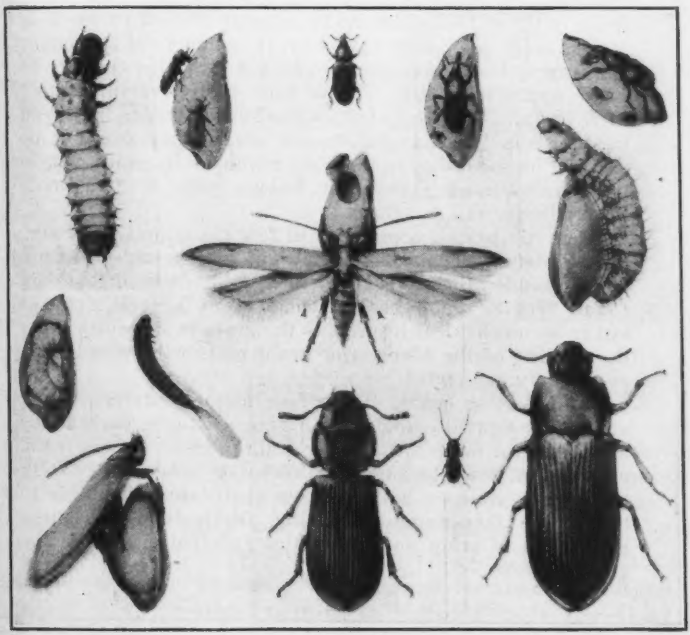

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MOST of the damage done by insects to grain in storage and shipments is due to four species. These are the granary weevil, the rice or black weevil, the lesser grain borer or Australian weevil, and the Angoumois grain moth. Others of the 40 species or groups of species described in this bulletin can cause great damage to grain if storage conditions are unusually favorable for their increase. Yet if grain in the unbroken kernel remains unaffected by the four insects mentioned, it is not likely, in commercial storage or shipments, to be sufficiently affected by other insects to cause appreciable loss. These four pests live throughout their larval life entirely within the kernel, where they feed unseen, usually unsuspected, and where they can not be reached by the ordinary methods employed by grain men in their grain-cleaning operations known to the trade as moving, fanning, and screening.

The other pests discussed, with few exceptions, are "surface feeders." Their larvæ may eat into kernels of grain and lie hidden there, yet the greater proportion of them are found feeding upon broken surfaces of kernels exposed either by mechanical injuries to the grain in handling or by the feeding of the four major grain pests with which they are usually associated.

The larvæ, or grubs, of the four major pests mentioned are not ordinarily capable of a free existence outside the kernel but the larvæ of the other grain pests are, in the main, capable of free locomotion, crawling where they will throughout grain in bulk, and are therefore susceptible to removal by fanning and screening. Methods of preventing infestation of grain and of treating infested grain are discussed briefly.

STORED-GRAIN PESTS.

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POPULAR CLASSIFICATION OF GRAIN PESTS.

Since the establishment of the Federal standards for grain under the provisions of the Grain Standards act, Federal grain supervisors and federally licensed grain inspectors are required to identify the various species of "live weevils and other insects injurious to stored grain" which may be present in the grain, and uniform names for grain insects should be used. Such uniform terminology will indicate definitely to all interested persons, including shipper, purchaser, and elevator operator, the exact nature of the insect found. Of the four major pests, the granary weevil, the rice or black weevil, and the lesser grain borer may be well called "grain weevils." The fourth of the major pests, the Angoumois grain moth, so destructive to wheat and corn, may be called "grain moth." Other insects likely to be found in any lot of grain may be called simply "beetles," "moths," and "mealworms," for their presence usually does not indi-

cate a condition likely to affect the trade, provided that after the grain has reached the elevator it is screened and fanned to remove these insects.

The writers have divided the insects discussed in this bulletin into grain weevils, grain borers, grain moths, flour moths, mealworms, grain and flour beetles, psocids, and mites. In some respects this is not a satisfactory grouping, especially for the insects listed as "grain and flour beetles," but it has the advantage of definitely placing the most serious insects troublesome in bulk grain.

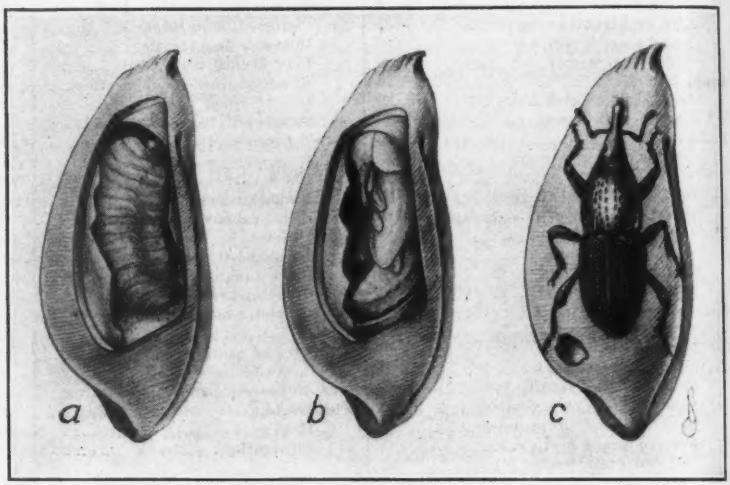

FIG. 1.—Life stages of the granary weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult. Note hole in kernel made by the adult in order to leave the seed, and hole that it is eating into the kernel for the purpose of laying eggs. This weevil closely resembles the rice weevil but has no papery wings beneath its wing covers, and the dot-like punctures on the back behind its head are elongate rather than round.

GRAIN WEEVILS.

Of the four true weevils that attack grain in the United States only two are of primary importance at present, the granary weevil and the rice or black weevil. The broad-nosed grain weevil and the coffee-bean weevil are of minor importance except locally. These four weevils have an elongated beak or snout, as shown in the illustrations, though the beak of the coffee-bean weevil is greatly reduced.

GRANARY WEEVIL.[1]

The granary weevil (fig. 1) is a small, moderately polished, chestnut brown or blackish beetle with head prolonged into a long slender snout at the end of which are a pair of stout mandibles or jaws. It is

[1] *Sitophilus granarius* L.

not more than three-sixteenths of an inch long, and often smaller. It has no wings under its wing covers and the thorax is well marked with longitudinal punctures, two characteristics that distinguish it from the closely related rice weevil, with which it is often found associated. The well-grown footless whitish grub or larva and the pupa are shown at *a* and *b*, respectively, in figure 1. The granary weevil is one of the oldest known insect pests, is a universal feeder upon grains, and is cosmopolitan, having been carried by commerce to all parts of the world. It prefers a temperate climate and is more frequently found in the Northern States than in the South.

Both adult and larva feed voraciously on a great variety of grains. The adult weevils may live for 10 or more months, and during this period each female may lay from 200 to 300 eggs. Before laying her eggs the female bores a small hole in the grain berry with her snout. When this is made she turns about and lays in it an egg, which she then covers with a gelatinous fluid which seals the hole. The small white fleshy and legless grubs that hatch from the eggs burrow about inside the kernel. When full grown, the grub transforms to the pupa stage and then into the adult weevil. In warm summer weather the granary weevil requires about four weeks to pass through the egg, larva, and pupa stages and emerge as an adult of the succeeding generation. The period of development may be prolonged greatly by cold weather.

RICE OR BLACK WEEVIL.[2]

The rice or black weevil is a small snout-beetle which varies considerably in size but rarely measures more than one-eighth of an inch in length (figs. 2 and 3). It varies in color from reddish brown to nearly black and is usually marked on the back with four light reddish or yellowish spots. It closely resembles the granary weevil in form, but it has well-developed wings beneath its wing covers, differs in color and markings, and has the thorax densely pitted with round, instead of longitudinal punctures. Figure 2 gives a good impression of the appearance of the rice weevil and its earlier stages.

This weevil has been known from early times. It is found in all parts of the world where grain is used and is one of the very worst pests in stored grain. It is particularly abundant in warm countries, where it breeds continuously and rapidly destroys all unprotected grain. Throughout the South it causes tremendous losses to corn (figs. 4, 5, 6, and 7) and is the commonest of the serious pests of commercial grain shipments.

The adult weevil lives, on an average, four or five months, each female laying between 300 and 400 eggs during this period. The

[2] *Sitophilus oryza* L.

early stages are almost identical in habit and appearance with those of the granary weevil and need not be further described. The rice

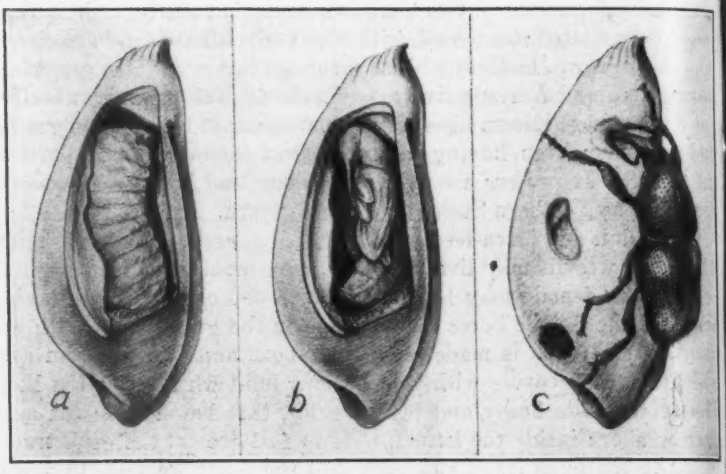

FIG. 2.—Life stages of the rice or black weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult feeding upon kernel. Note in *c* the hole in lower portion of kernel made by the adult on leaving the seed, and at two points higher up shallow holes made by the adult in feeding upon the seed after emergence. The adult weevil is at once distinguished from the granary weevil, shown in figure 1, by the four light reddish brown or yellow spots on its wing covers, by the possession of wings beneath the wing covers, and by the many rounded punctures on the back behind its head.

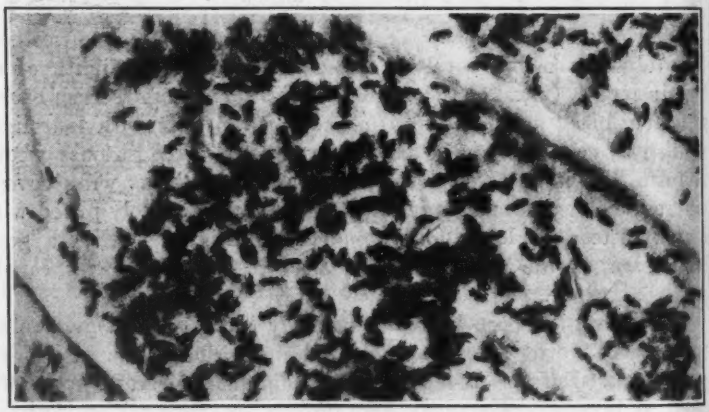

FIG. 3.—The rice or black weevil: Many adult weevils caught in the mesh of a cloth sack containing pearled barley. Compare their size with that of the barley kernels. Adult weevils when disturbed usually "play possum," but if spread upon a cloth in the sun the live ones will soon show signs of life.

weevil is a strong flier. The adults fly from granaries to the fields of grain and there start the infestation that often proves so disastrous after the grain has been harvested. During summer weather

FIG. 4.—Ear of corn with a poor, loose shuck. It is badly infested with rice or black weevils. As the adult weevils feed, they push from the kernels the chewed-up portions, frass, etc., and this material, resembling white dust, collects in larger quantities between the kernels and the shuck, or, if the ears are shucked, it falls like powder onto any object below the ear. (Back.)

FIG. 5.—An ear of corn badly damaged by rice or black weevils. This ear has been hit against a table to jar loose the powdery substance, sometimes called the farinaceous material, and so reveals the great damage done by the weevils. The kernels of the ear have been reduced to powder and shell. (Back.)

the egg, larva, and pupa stages may be passed in as few as 26 days. This period, of course, is greatly prolonged during cool or cold weather. For a further discussion of this pest see Farmers' Bulletin 1029, United States Department of Agriculture.

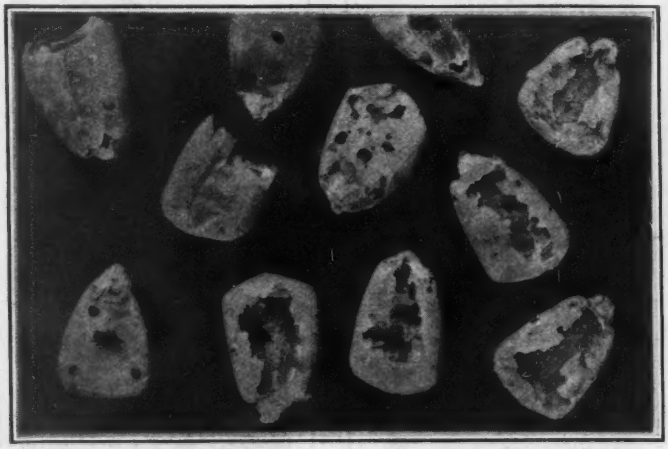

FIG. 6.—Kernels of corn taken from badly infested ear corn, showing how the rice or black weevils can thoroughly destroy all parts of the kernels. (Back.)

BROAD-NOSED GRAIN WEEVIL.[3]

The broad-nosed grain weevil is a small dark-brown snout-beetle slightly less than one-eighth of an inch long. In form and color it resembles the granary weevil somewhat but differs from it and other grain-infesting weevils by having a short, broad snout (see figure 8.)

This weevil is occasionally found in Georgia and South Carolina and is wide-spread in Florida, where it is a serious pest of stored grains. It is unable to breed in dry, hard, uninjured grain, but attacks soft or damaged grain, or grain that has been attacked by other grain insects. It is a strong flier, and, like the rice weevil, flies to the cornfields and infests the grain before it becomes fully hardened.

The adult weevils normally live for about five months, and during this time the females lay between 200 and 300 eggs. The small white eggs are usually laid in broken portions of the grain. They hatch in a few days, and the small, white, legless grubs feed on the softer portions of the grain until they become fully grown. They then change to a white pupal form which in a few days transforms to the

[3] *Caulophilus latinasus* Say.

adult beetle and cuts its way out of the grain. The period from egg to adult in summer is about one month.

COFFEE-BEAN WEEVIL.[4]

The coffee-bean weevil is a very active, robust beetle from two-sixteenths to three-sixteenths of an inch long; dark brown in color, clothed with a mottled light and dark-brown pubescence. It may be easily recognized from the accompanying illustration (fig. 9).

This weevil is found in many countries and is extremely abundant in the Southern States, where it breeds in dried fruit, coffee berries, cornstalks, corn, and the seed and seed pods of an almost endless variety of plants. It is a strong flier and is frequently to be seen in the cornfields of the South on the exposed and damaged ears. It lays its eggs in the soft kernels of corn and breeding continues after the corn has been harvested and placed in storage. It does not cause much damage to corn in storage, as the corn becomes too hard to be attractive. It may, however, be very abundant locally in corn in Florida during the first three months of storage, and has been reported as com seeds in Honolulu. Taking the country at large, the coffee-bean weevil is a very minor grain pest. Figure 10, *a* and *b*, shows the rather characteristic holes cut in the kernels of corn and in corn shucks by the larvæ and emerging adults.

FIG. 7.—Slip-shuck corn showing holes eaten through the shuck by the rice or black weevil. These holes make passages through which all kinds of grain pests move back and forth to bring about a more speedy destruction of the kernels. (Back.)

[4] *Araecerus fasciculatus* DeG.

GRAIN BORERS.

Two species of grain borers are now established in the southern States. The *lesser grain borer* bids fair to become a very serious

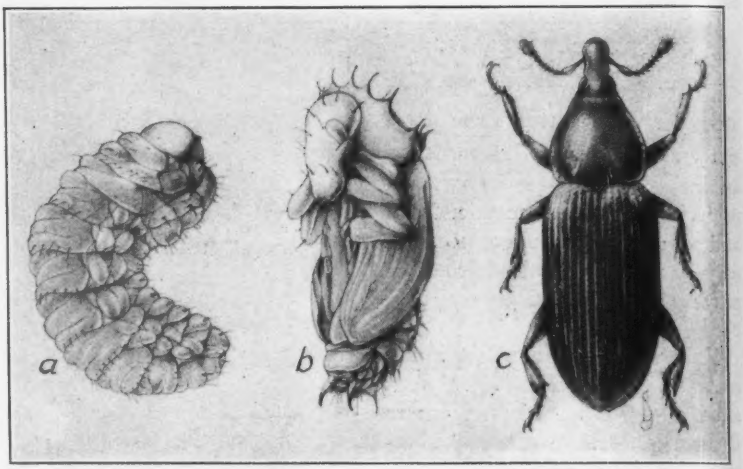

FIG. 8.—The broad-nosed grain weevil: *a*, Full-grown larva; *b*, pupa; *c*, adult weevil. This weevil is not found in northern-grown grains. It is now present in the southeastern Gulf States. The adult weevil is slightly less than one-eighth of an inch long. It is distinguished from the rice and granary weevils by its much shorter beak.

pest of grain throughout the South. The *larger grain borer* has not yet become a factor in commercial shipments of grain.

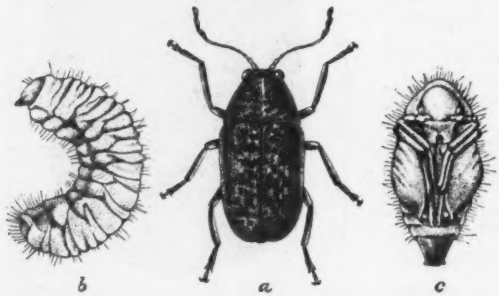

FIG. 9.—The coffee-bean weevil: *a*, Adult; *b*, well-grown larva; *c*, pupa. The adult is about three-sixteenths of an inch long, of a dark brown color covered with a light and dark brown hairiness. (Chittenden.)

LESSER GRAIN BORER.[5]

The lesser grain borer, known to many grain dealers more popularly as the "Australian wheat weevil," because of the large supplies of wheat infested by it that reached this country from Australia during the war, is one of the smallest beetles injurious to grain in this country. It appears to be steadily spreading throughout the South, and infested grain

[5] *Rhizopertha dominica* Fab.

has been found in Texas, Kansas, Oklahoma, Louisiana, Florida, and California, besides at many points of entry. It is readily distinguished from other grain pests by its slender cylindrical form and small size. It is a polished dark brown or black in color, with a

FIG. 10.—Work of the coffee-bean weevil: *a*, Holes made in corn shucks by the adult weevils eating their way out from the kernels beneath; *b*, two kernels in which larvæ of this insect have developed. Note that a single larva devours a large portion of a single kernel, which is not true of the rice weevil.

somewhat roughened surface, about one-eighth of an inch long and one thirty-second of an inch wide. Its head is large, prominent, and bent down under the thorax. The larva, pupa, and adult stages are illustrated in figure 11. It belongs to a family[6] of beetles that have

[6] Bostrychidæ.

the head turned down under the thorax and are armed with powerful jaws with which they can cut directly into wood. Originally native

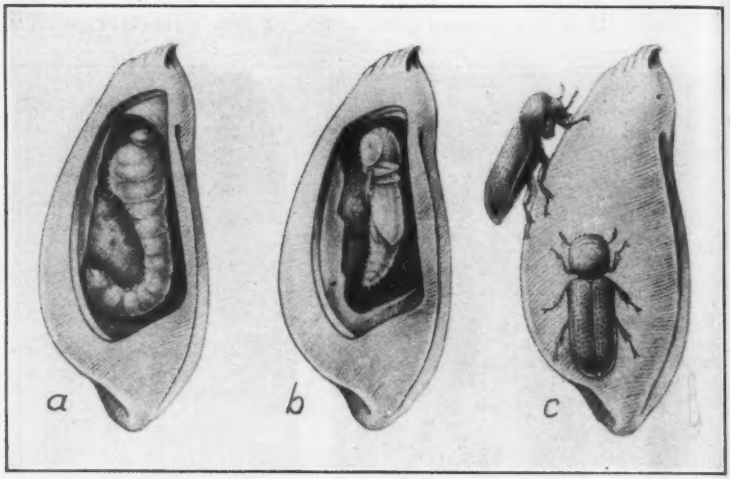

FIG. 11.—The lesser grain borer in wheat kernels: *a*, The well-grown larva; *b*, the pupa; *c*, two adult weevils. Adult borer is shiny roughened dark brown or black, about one-eighth of an inch long.

to the tropics the lesser grain borer has spread through commerce to all parts of the world.

Both beetles and larvæ cause serious damage in warm climates, attacking a great variety of grains. The destruction of which they

FIG. 12.—Kernels of wheat thoroughly riddled and devoured by the boring and feeding of the lesser grain borer and its larva. Such damaged kernels are always surrounded by much powder or flour-like material which the insects have chewed up and pushed out from the kernels.

are capable is shown by the wheat kernels of figure 12, which are literally riddled by the boring adults and their young. The females

lay from 300 to 500 eggs each, dropping them singly or in clusters in the loose grain. The eggs hatch in a few days and the small whitish grubs crawl actively about the grain, feeding on the flour produced by the boring of the beetles, or boring directly into grains that have been slightly damaged. They complete their growth within the grain, transform to white pupæ, and in time change to adult beetles which cut their way out of the grain. The period from egg to adult in summer is said to be about a month.

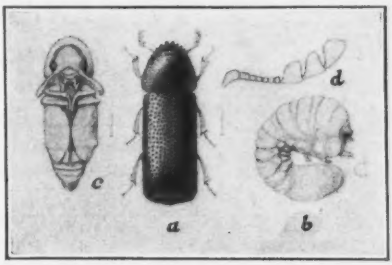

FIG. 13.—The larger grain borer: *a*, Adult insect; *b*, larva; *c*, pupa; *d*, antenna of adult. Adult borer is shiny polished dark brown, about one-sixth of an inch long. *a*, *b*, *c*, About six times natural size; *d*, highly magnified. (Chittenden.)

LARGER GRAIN BORER.[7]

The larger grain borer is a small, dark brown, elongate-cylindrical beetle about one-sixth of an inch long. As may be seen in figure 13, it is very similar in appearance to the lesser grain borer, but may be distinguished by its larger size and comparatively smooth, polished surface.

This beetle is a tropical insect not as yet widely distributed in this country. It is occasionally found infesting corn (fig. 14) in the Southern States. Its habits are similar to those of the lesser grain borer. It, also, has probably acquired its grain-feeding habits rather recently.

FIG. 14.—Kernel of corn showing work of adult of larger grain borer. The adult borers tunnel in all directions and reduce kernels to powder and shells. Enlarged. (Chittenden.)

GRAIN MOTHS.

The grain moths include only those moths capable of destroying sound, unbroken grain kernels. They are not so abundant as the flour moths, which are principally pests in broken, damaged kernels or milled products.

ANGOUMOIS GRAIN MOTH.[8]

The Angoumois grain moth is a small buff or yellowish brown moth with a wing expanse of about one-half inch. This is the moth most commonly found in infested grain in this country and is not likely to be confused with any other. It attacks all cereal grains, is found in all parts of the world, and is particularly injurious in the South, where it attacks grain both in the field and in storage.

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[7] *Dinoderus truncatus* Horn. [8] *Sitotroga cerealella* Oliv.

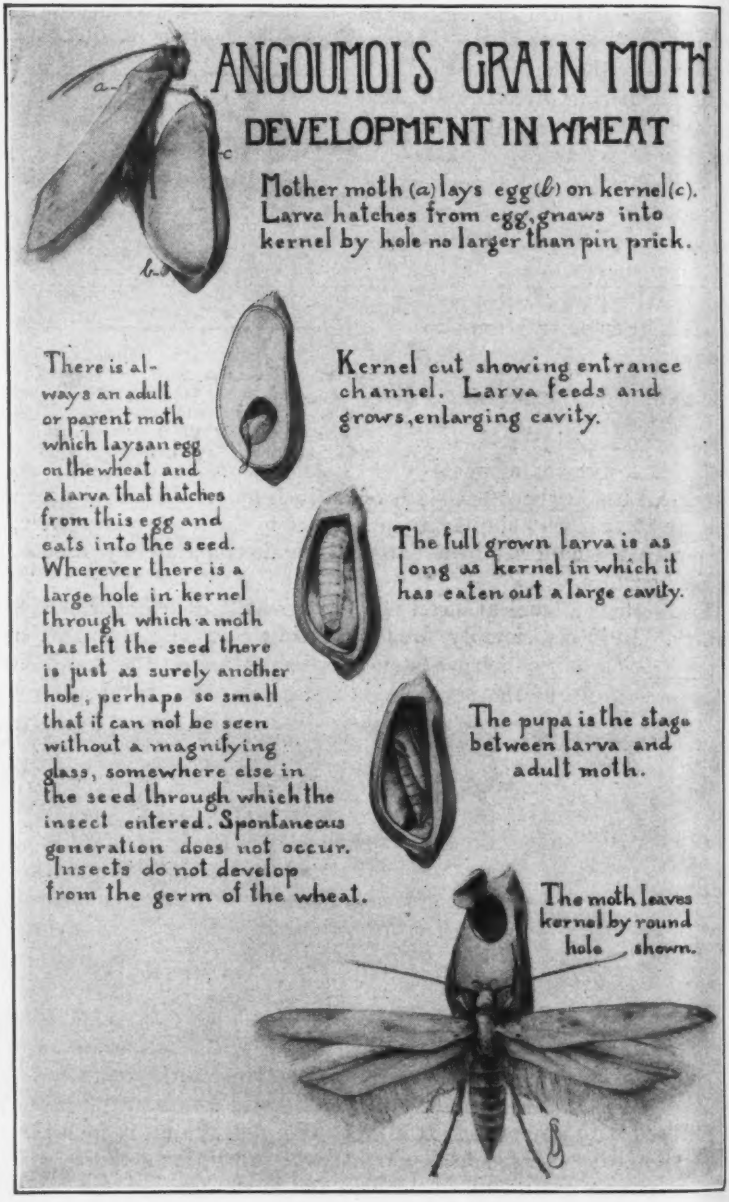
ANGOUMOIS GRAIN MOTH
DEVELOPMENT IN WHEAT
Mother moth (a) lays egg (b) on kernel (c). Larva hatches from egg, gnaws into kernel by hole no larger than pin prick.
There is always an adult or parent moth which lays an egg on the wheat and a larva that hatches from this egg and eats into the seed. Wherever there is a large hole in kernel through which a moth has left the seed there is just as surely another hole, perhaps so small that it can not be seen without a magnifying glass, somewhere else in the seed through which the insect entered. Spontaneous generation does not occur. Insects do not develop from the germ of the wheat.
Kernel cut showing entrance channel. Larva feeds and grows, enlarging cavity.
The full grown larva is as long as kernel in which it has eaten out a large cavity.
The pupa is the stage between larva and adult moth.
The moth leaves kernel by round hole shown.

FIG. 15.—Life cycle of Angoumois grain moth on wheat. (Back.)

Each female moth may lay as many as 150 eggs, which are white when first laid but soon change to a reddish color. The eggs are laid on or near the grain. Upon hatching, the minute white larva or caterpillar bores into a kernel of grain and begins feeding on the contents. When full grown it eats out a channel to the outside of the seed but leaves a thin layer of the seed coat intact. It then changes to a reddish brown pupa, and later the adult or moth emerges, pushing aside the thin section of seed coat that covers the exit from the channel. The development from egg to adult may be completed in five weeks. Figures 15 and 16 show the successive stages in the development of

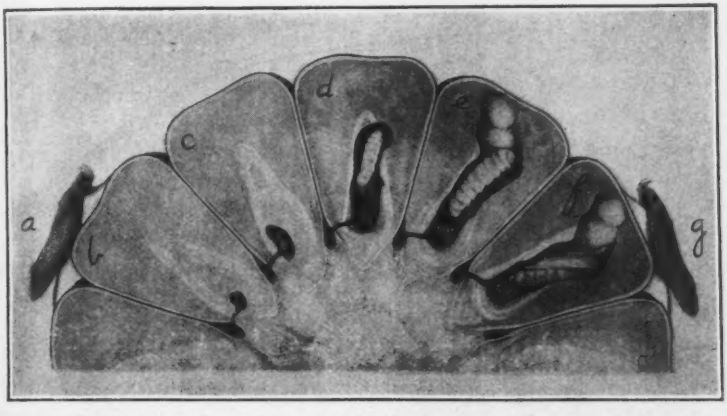

FIG. 16.—Cross section of ear of corn showing development of Angoumois grain moth in corn. The newly hatched larva crawls down to the germ end of the corn and begins feeding upon the soft germ. As it grows older and stronger it eats out into the firmer portion of the kernel and finally, in most instances, eats to the outer end. (Back.)

this insect in a kernel of wheat and of corn from the time the egg is laid until the adult appears. In figure 17 is shown an ear of corn with the external evidence of heavy attack, and in figure 18 are shown wheat kernels with the emergence holes of the moth. For a further discussion of this pest see Farmers' Bulletin 1156, "The Angoumois Grain Moth."

WOLF MOTH.[9]

The wolf moth is a small moth about the size of the Angoumois grain moth, creamy white and thickly mottled with brown. The mottled appearance distinguishes it from the Angoumois grain moth. It infests all kinds of grain, both in the field and in storage. The larva feeds on the grain and webs the kernels together.

[9] *Tinea granella* L.

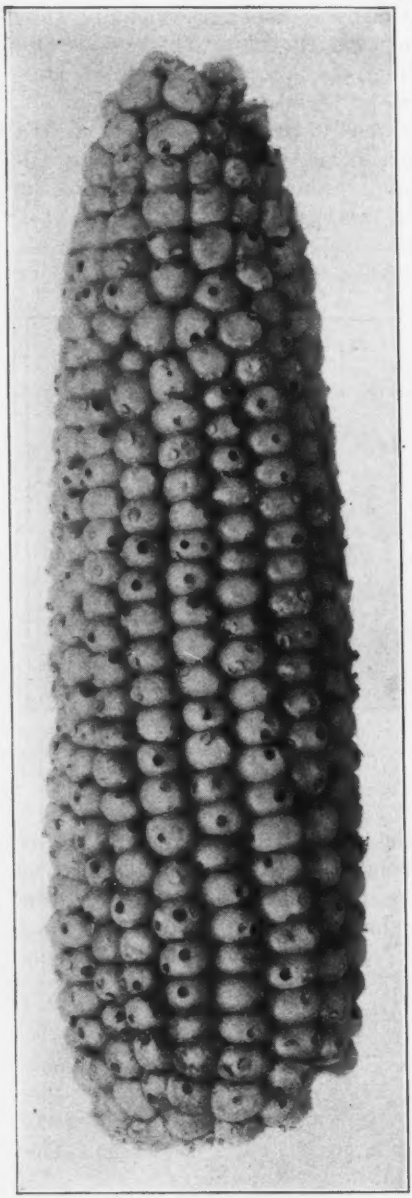

FIG. 17.—Ear of popcorn showing heavy infestation by the Angoumois grain moth. Note that certain of the kernels have three emergence holes, and that many have served as food for two moths. The development of a single insect in a kernel causes a loss of from 13 to 24 per cent in weight.

The wolf moth is distributed throughout the Northern States but is not very abundant and can not be compared with the Angoumois grain moth for destructiveness.

PINK CORNWORM.[10]

The pink cornworm is the larva or caterpillar of a small moth (fig. 19). It is about five-sixteenths of an inch long when full grown; pink in color, with head and thoracic shield pale brown. Figure 20 gives a good idea of its appearance. The moth which develops from this worm or larva is smaller than the Angoumois grain moth, with a wing expanse of slightly less than half an inch. The forewings are banded and mottled with yellow, reddish brown, and black, as shown by figure 19. The pale grayish hindwings are very slender and are edged with long fringes. The pupa is shown in figure 21.

This insect is common in the South, where it causes considerable injury to

[10] *Pyroderces rileyi* Wals.

corn, both in the field and in storage. Infestation begins in the field and is continued after the corn is placed in storage. The very characteristic injury is shown in figures 22 and 23. The large amount of frass that is loosely webbed together and fills the interstices between the kernels or is crowded into the cavities of kernels that have been eaten out is a reliable indication of the presence of this pest. The pearly white eggs are laid singly or occasionally in twos or threes. The pinkish larvæ feed on the seed, husk, and cob with equal relish. Though capable of serious injury to corn, in particular as it comes

FIG. 18.—Kernels of wheat showing the small round emergence holes that prove that the Angoumois grain moth has developed in the seed, thus reducing the weight somewhat over 50 per cent. (Back.)

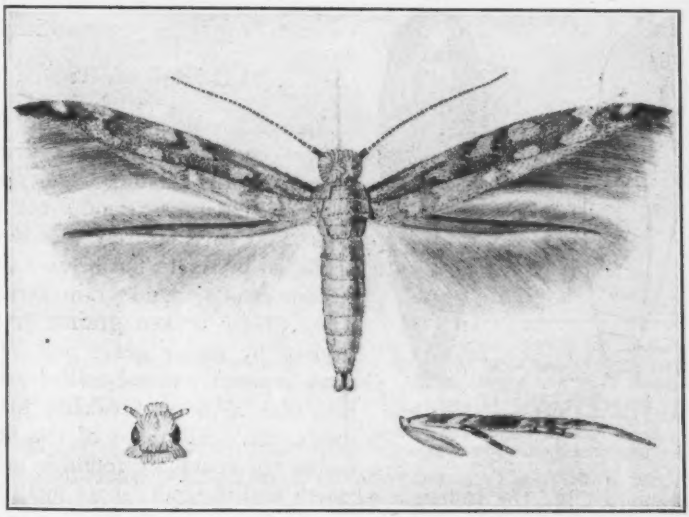

FIG. 19.—The pink cornworm: Moth, much enlarged; head and leg more enlarged. The moth has a wing spread of a little less than half an inch. (Chittenden.)

to maturity in the field, and while in the cribs on Southern farms, the pink cornworm is seldom a serious pest of commercial shipments.

RICE MOTH.[11]

The rice moth has a wing expanse of about half an inch and is of a pale grayish brown or tawny color. Its characteristic appearance is shown in figure 24. The larva (fig. 25) resembles somewhat that of the Indian meal moth, being when full grown about half an inch

FIG. 20.—The pink cornworm: Full-grown larva, side view, greatly enlarged. When full grown the larva is pink and about five-sixteenths of an inch long. (Chittenden.)

long and varying in color from white to a dirty, slightly bluish gray with occasional tints of green. Damage by the pest, as in the case of all moth pests, is done by the larvæ, which feed upon rice, cocoa, chocolate, ships biscuits, etc. The larvæ produce a dense webbing as they become well grown. When feeding upon grains they spin dense silken tubes, webbing the grain kernels into the walls of the tubes. The pupa is shown in figure 26. The rice moth is seldom found in this country and has not become very widely disseminated.

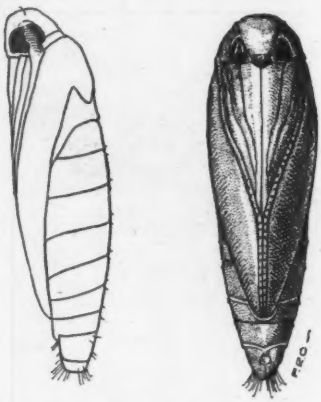

FIG. 21.—The pink cornworm: Pupa, ventral view at right, lateral view at left. Enlarged. (Chittenden.)

FLOUR MOTHS.

Among the flour moths are some of the commonest and most serious pests of grain products. They are designated as flour moths not because they feed entirely upon flour or milled products, but because they seldom attack sound grain kernels. They prefer broken grains, grains injured by major grain pests, and more especially cereal milled products such as flour, breakfast foods, meals, etc. All three of the flour moths are commonly found in grain warehouses, but the Indian meal moth and the meal snout moth are probably the most frequently reported. These two moths may, under specially favorable conditions, become established in whole grain and other seeds and cause injury especially by eating out the germ.

[11] *Corcyra cephalonica* Staint.

INDIAN MEAL MOTH.[13]

The Indian meal moth is a rather handsome moth with a wing expanse of nearly three-fourths of an inch. It is easily distinguished from other grain pests by the peculiar marking of its forewings. These are reddish brown with a coppery luster on the outer two-thirds, but whitish-gray on the inner or body end. Moths and larvæ are shown in figure 27. The female moths lay from 300 to 400 eggs,

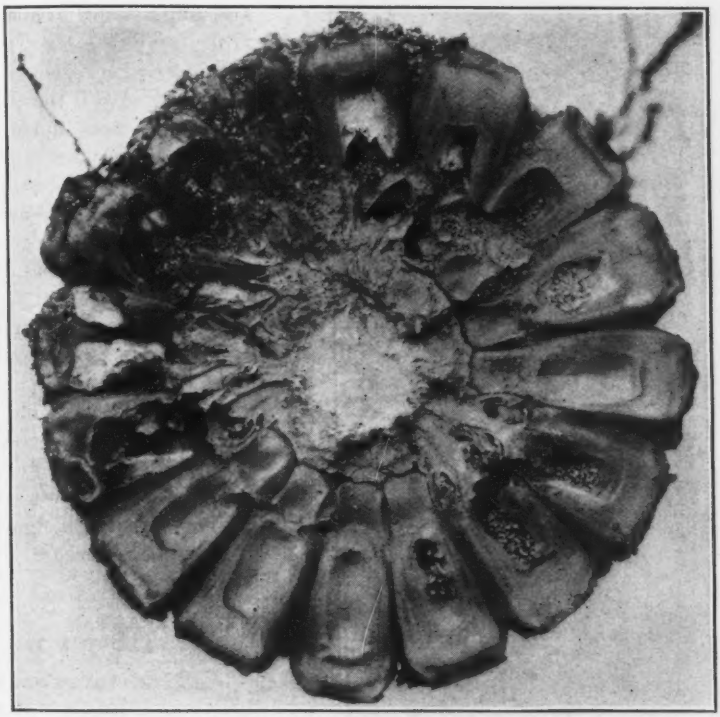

FIG. 22.—Ear of corn cut to show characteristic feeding and destruction by pink corn-worm larvæ. Note that the larvæ eat from one kernel to another, often severing the kernels from the cob. The larvæ sometimes eat into the cob and there transform to the pupa stage. The pupæ are about one-third as long as the kernels shown.

singly or in groups, on food material. The eggs hatch within a few days into small whitish larvæ or caterpillars. These larvæ feed upon grains, grain products, dried fruits, nuts, and a rather wide variety of foodstuffs. When full grown, the larvæ are about half an inch long, dirty white in color, varying sometimes to greenish and pinkish hues. A full-grown larva is shown in figure 28, clinging to a kernel

[13] *Plodia interpunctella* Hbn.

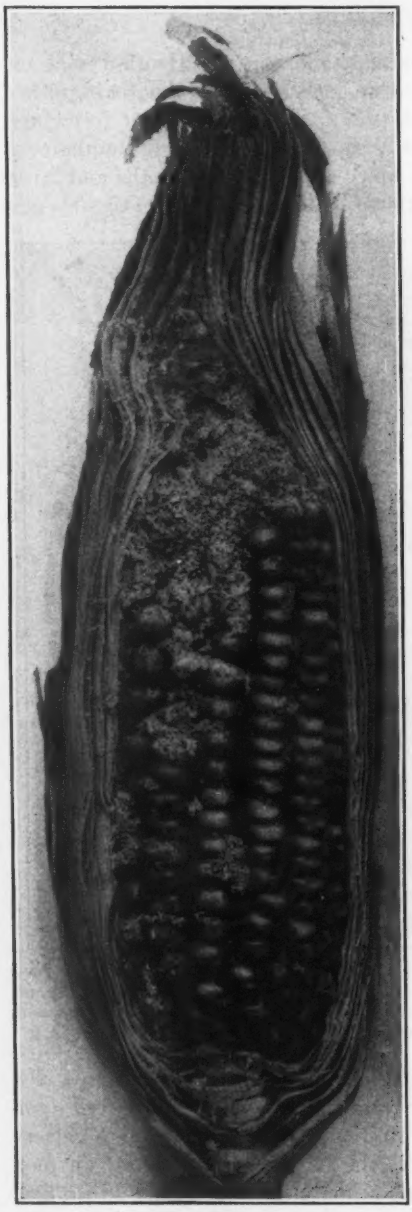

FIG. 23.—Ear of corn with portion of shuck removed to show surface feeding by larvæ of the pink cornworm. Often many kernels drop from the ear when the shucks are removed because of the feeding of the pink cornworm larvæ.

of wheat. This larva spins a silken cocoon and transforms to a light-brown pupa from which the parent moth later emerges. The Indian meal moth may pass through its egg, larva, and pupa stages in about four weeks—during warm weather.

The larva of the Indian meal moth spins a web as it becomes full-grown, and leaves behind a silken thread wherever it crawls. When sacks of cracked corn, meal, or corn in the ear that has been previously injured by other pests become heavily infested, this webbing often is sufficiently abundant to attract attention. The loosely clinging web shown on the ear of corn in figure 29 is characteristic of this pest.

MEDITERRANEAN FLOUR MOTH.[13]

The Mediterranean flour moth has a wing spread of slightly less than one inch. Its hind-wings are a dirty white, but its forewings, which alone show when the moth is not flying, are a pale leaden gray with transverse wavy black markings. (See fig. 30.)

[13] *Ephestia kuehniella* Zell.

The Mediterranean flour moth is a native of Europe. Its first discovery in the United States was in California in 1892. Since then it has spread to practically all the States of the Union and is recognized as the most serious pest of flour mills, owing to the silken threads

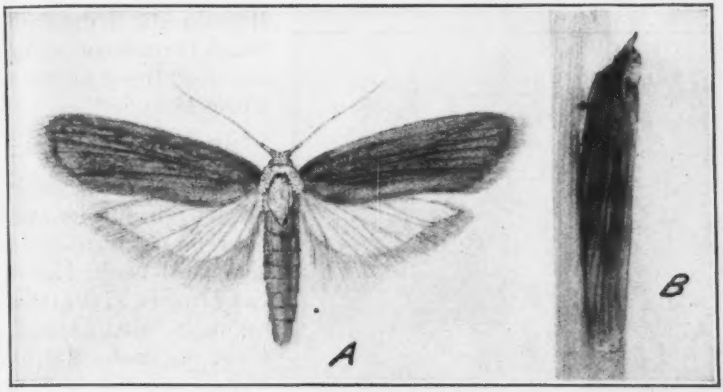

FIG. 24.—The rice moth: *a*, Mature moth, dorsal view, with wings spread; *b*, side view of same moth with wings folded about body. The moth is of a grayish brown or tawny color, with a wing spread of about half an inch. Much enlarged. (Chittenden.)

which the larvæ spin wherever they crawl. These webs mat the flour or meal together and eventually clog machinery so that mills have to shut down for a thorough cleaning and treatment. Although preferring flour and meal, the Mediterranean flour moth attacks grain, bran, and cereal products and is commonly found in storehouses and granaries.

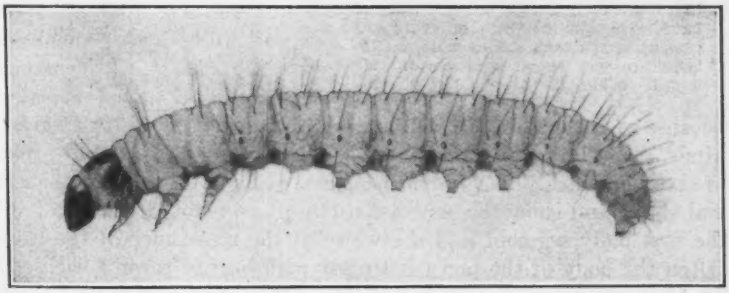

FIG. 25.—Full-grown larva of the rice moth. The full-grown larva is about one-half inch long, and is of a whitish or bluish gray color. Much enlarged. (Chittenden.)

The female moth lays small white eggs in accumulations of flour, meal, or waste grain. From the eggs the small larvæ hatch in a few days. When full grown, these are about half an inch long and are of a whitish or pinkish color with a few small black spots on the body.

The full-grown larva spins a silken cocoon in which the insect transforms to a reddish-brown pupa. Later the parent moth emerges from the pupa. During warm weather, the Mediterranean flour moth requires about nine weeks to pass through its egg, larva, and pupa stages. A more complete discussion of this pest will be found in Bulletin 872 of the United States Department of Agriculture, "Insect Control in Flour Mills."

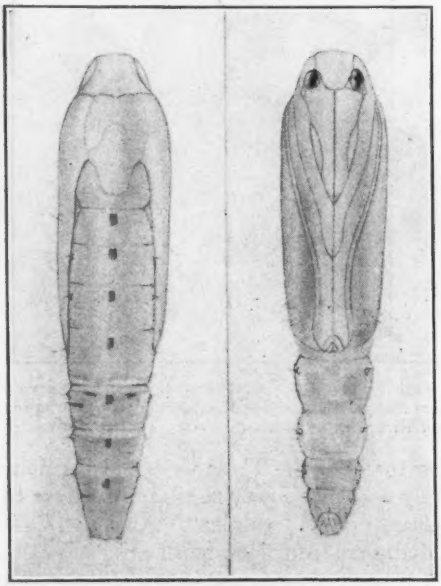

FIG. 26.—Pupa of the rice moth: At left, dorsal view; at right, ventral view. The pupa is found in a dense tough cocoon into the walls of which have been spun particles of the food. The cocoons of the Indian meal moth, on the other hand, are very loosely constructed. Much enlarged. (Chittenden.)

MEAL SNOUT MOTH.[14]

The meal snout moth is brownish in color, somewhat larger than the Indian meal moth, though varying in size, usually having a wing spread of about one inch. Its forewings are marked in a characteristic pattern indicated in figures 31 and 32; they are light brown with dark brown patches at base and tip and each with two wavy transverse white lines. The meal snout moth is widely distributed and a general feeder in the larva stage upon cereals of all kinds both ground and in the berry. It sometimes attracts much attention because of its capacity to web up and bind together seeds of various kinds. The larvæ are whitish and attain a length when full grown of about one inch. The two larger larvæ of figure 31 indicate the normal shape and show the contrast between the black of the head and the first body segment and the white of the remainder of the body. Often the body of the larva is tinged with orange toward each end. The larvæ spin peculiar tubes of silk and particles of the food material. They rest in these tubes, which are very tough, and feed from the openings at the ends. When full grown the larvæ leave the tubes, spin silken cocoons, often covered with food particles, and transform to the pupæ from which later emerge the adult moths.

[14] *Pyralis farinalis* L.

The meal snout moth may require only eight weeks to pass through the egg, larva, and pupa stages.

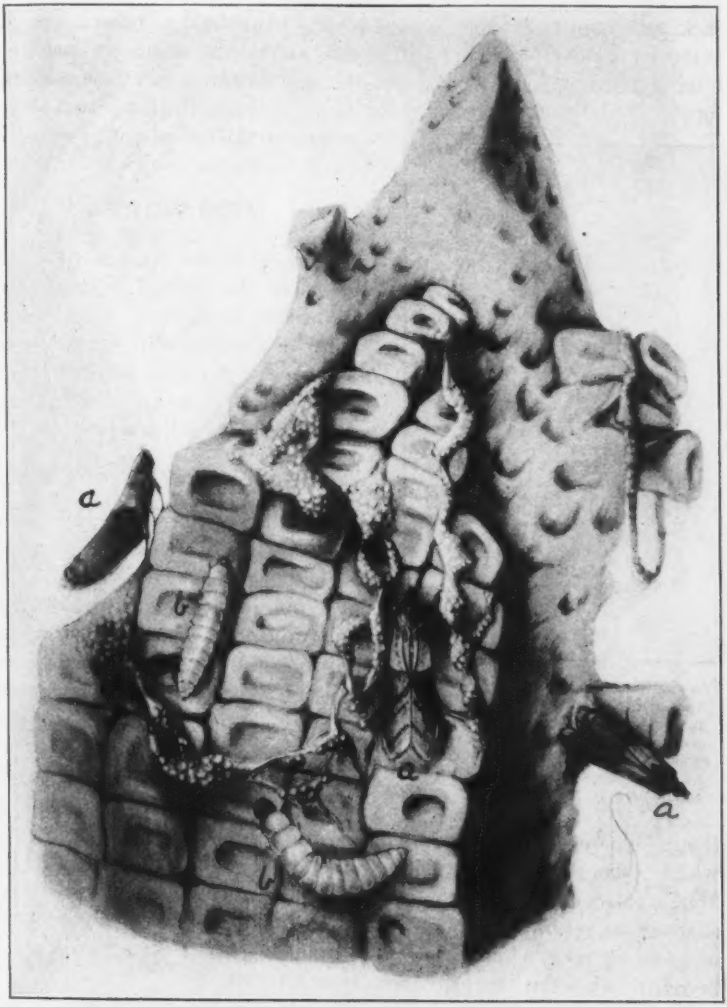

FIG. 27.—The Indian meal moth: Tip of ear of corn showing, *a*, three moths with their characteristic light and dark markings, and *b*, two well-grown larvæ. The adult moth is distinguished from all other grain-infesting moths by having the outer two-thirds of its wings brownish and the inner third whitish gray. It has a wing spread of about three-fourths of an inch.

The meal snout moth is primarily a pest of seeds that are held for some time in cool and damp localities. Outbreaks that have come to the attention of the authors have always been centered in

grain that was harvested during rainy weather or so stored that the moisture content was unusually high. Attempts to rear the moth in dry, warm laboratories have failed. The larvæ cut through burlap sacking and can damage sacks greatly when heavy infestations develop in sacked material. Figure 33 shows the characteristic webbing together of infested seeds—in this instance navy beans—and figure 32 shows the tendency for larvæ to spin their whitish silken cocoons on the outside of grain sacks where the sacks touch each other.

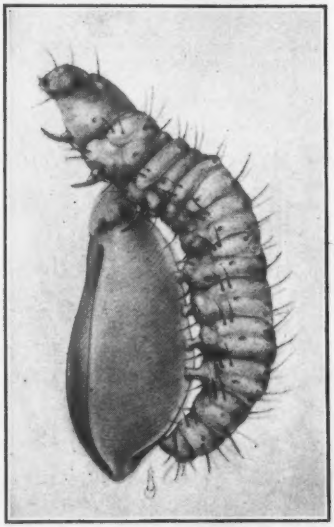

FIG. 28.—Well-grown larva of the Indian meal moth, crawling on kernel of wheat. These worms are white or greenish in color and frequently eat out the germ end of wheat. They attain a length of about half an inch.

MEALWORMS.

There are two species of mealworms in the United States. The adults are the largest of the beetles found in grain and their larvæ are conspicuous, for they attain a length of about one inch and are as large around as an earthworm.

YELLOW MEALWORM.[15]

The adult of the yellow mealworm is a polished dark-brown or black beetle, somewhat more than half an inch long, with its thorax finely punctured and with its wing covers longitudinally striated or grooved. (See fig. 34, at right.) The females lay bean-shaped white eggs covered with a sticky secretion that causes the flour, meal, or grain waste in which they are placed to adhere to them. The eggs hatch in about two weeks into slender white larvæ, which soon turn yellow and assume the form shown in figure 34. When full grown, the larvæ are about an inch long and yellowish, shading to yellowish-brown toward each end and at the articulation of each segment. The pupa into which the larva transforms before becoming an adult beetle is shown in figure 34.

The yellow mealworm is widespread over the world and is frequently found in stored grains. It belongs to a family of beetles[16] known as the darkling beetles because of their preference for dark places. The adults fly only at night. During daylight they conceal themselves, with the larvæ, beneath sacks of grain, under grain boxes,

[15] *Tenebrio molitor* L.

[16] Tenebrionidae.

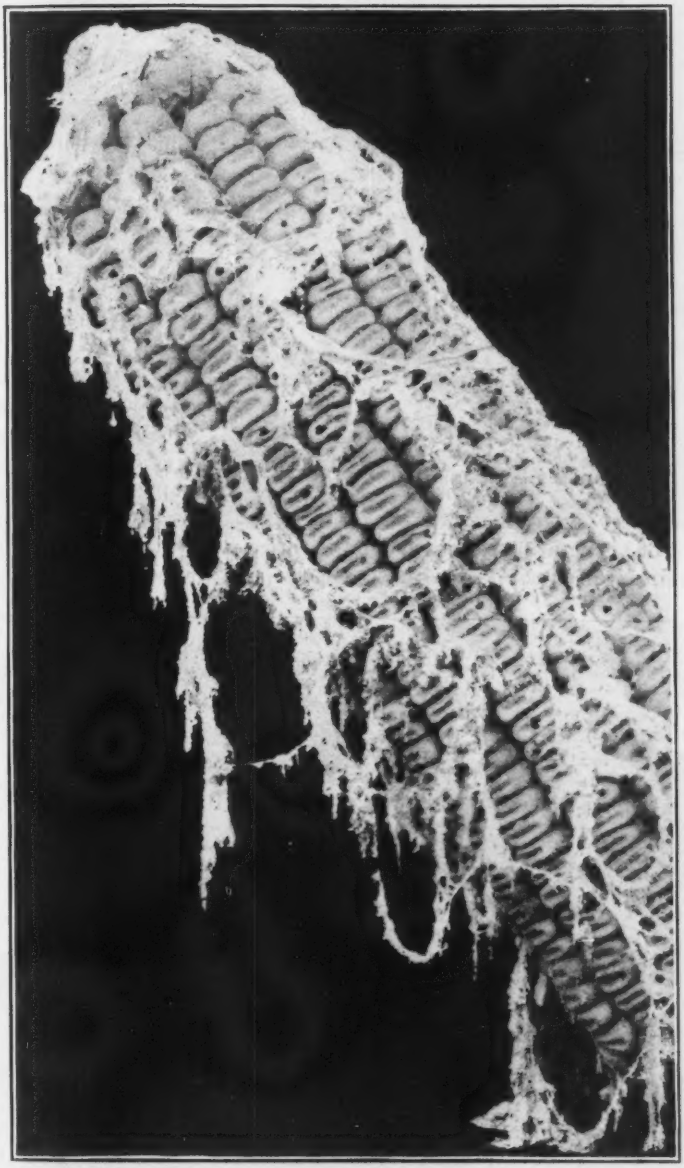

FIG. 29.—Ear of corn showing the loose webbing characteristic of the Indian meal moth larvæ. This moth rarely attacks sound grain, but, as is here shown, frequently attacks grains already injured by other grain pests. Such webbing as is here shown develops only when corn or other grains are left unmoved for some time.

or beneath grain and other food. There is but one generation each year. The adults begin to appear in the latitude of Washington during May and by June have laid most of their eggs and have died. Farther north the adults appear during June. The larvæ become full grown in about three months, but instead of transforming then to the adult stage they continue feeding and molting until cold weather and then hibernate as larvæ. The following spring they transform to the pupa stage, in which the insect passes about two weeks. Because the yellow mealworm has but one generation each year, and is entirely an external feeder upon grains, it need not be feared as a serious pest. Screening and fanning

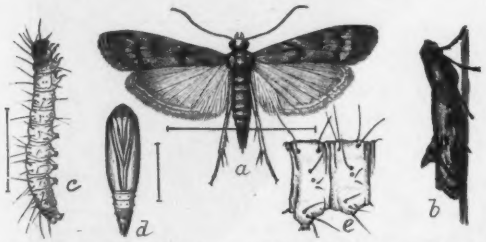

FIG. 30.—The Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa (enlarged); *e*, abdominal joint of larva (more enlarged). The adult moth, with a wing expanse of a trifle less than one inch, is leaden gray in color, marked with transverse wavy black markings. The full-grown larva is whitish or pinkish in color, with small black spots, and is about one-half an inch long. (Chittenden.)

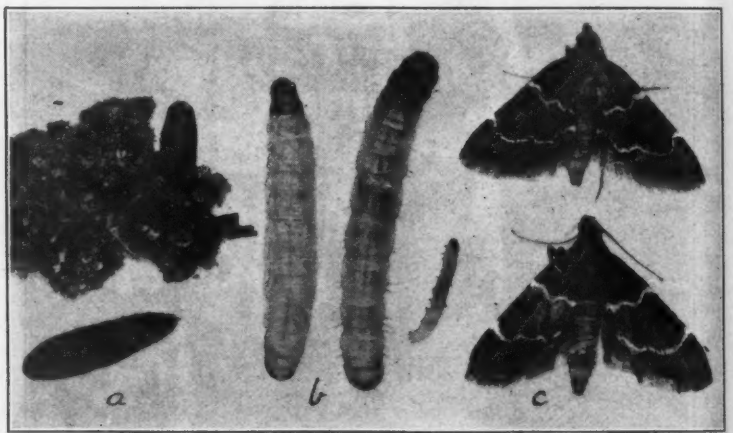

FIG. 31.—The meal snout moth: *a*, Pupa and, above, webbed mass of grain showing portion of pupa protruding; *b*, two well-grown larvæ with a smaller larva at right; *c*, two adult moths. Magnified about one and one-half times. The markings on the forewings easily distinguish this insect from other grain pests.

will remove it easily from grain shipments. The well-grown larvæ, however, can do serious injury to whole grains under certain conditions when grain is held for long periods without being moved.

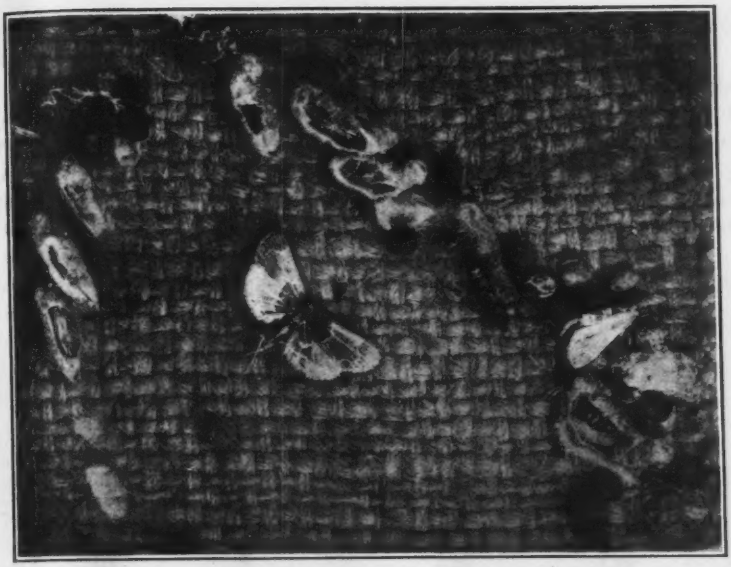

FIG. 32.—Inside of a grain sack that was filled with infested vetch seed. Note vetch seeds sticking to side of bag as a result of the webs of the larvæ of the meal snout moth, the numerous whitish cocoons with dark pupæ within, and, in the center, one adult moth. Natural size.

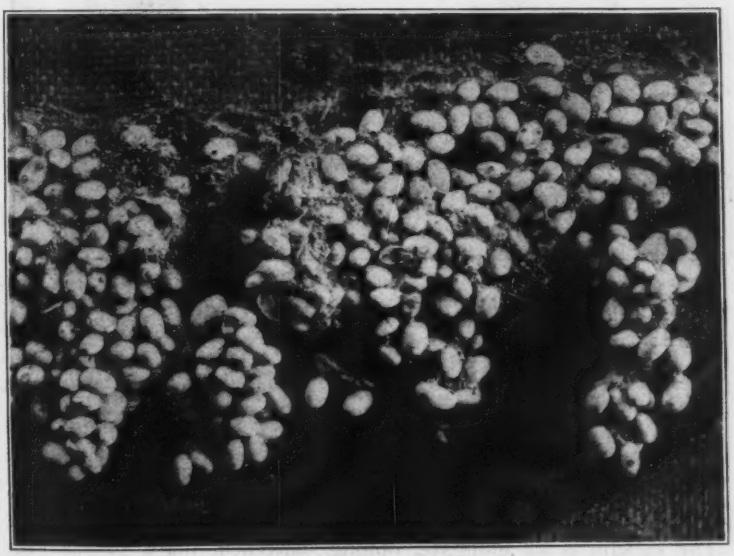

FIG. 33.—Navy beans webbed together by larvæ of the meal snout moth, and adhering to sack. The larvæ often cut sacks so seeds fall out and lodge where sacks touch each other. In these places the seeds are usually more heavily infested.

DARK MEALWORM.[17]

The dark mealworm, as may be seen by the larva, pupa, and adult shown in figure 35, is very similar in form, size, and color to the yellow mealworm, to which it is closely related. The adult beetle differs, however, in being dull pitchy black, in contrast to the shiny or polished dark brown or black of the yellow mealworm. Its larva so closely resembles the larva of the yellow mealworm that it can be distinguished most easily by its much darker color. The two

FIG. 34.—The yellow mealworm. Four well-grown larvæ, two pupæ, and the black adult beetle, with five kernels of wheat to indicate relative size. The larvæ when full grown are about one inch long and yellowish. The adult beetles are shiny black and slightly more than half an inch long.

species of mealworm are often found associated, and what has been said of the stages of the yellow mealworm applies equally well to the dark mealworm.

GRAIN AND FLOUR BEETLES.

CADELLE.[18]

The cadelle is an elongate, oblong, flattened, black or blackish beetle about one-third of an inch long. It resembles the mealworms

[17] *Tenebrio obscurus* Fab.

[18] *Tenebroides mauritanicus* L.

in appearance, but is much smaller and the thorax and abdomen are loosely joined. (See fig. 36.)

The larva of the cadelle is one of the largest of the grain-infesting insects and is easily recognized. It is about three-quarters of an inch long, fleshy, with the abdomen terminating in two dark horny points. The larva is a dirty or chalk white, with head, thoracic shield, and the two horny points at end of body black, as shown in figure 37.

This insect is widespread over the world and is frequently found in mills, granaries, and storehouses, where it infests flour, meal, grain, etc. Both larva and adult feed on grain and have the destructive habit of going from kernel to kernel and devouring the embryo.

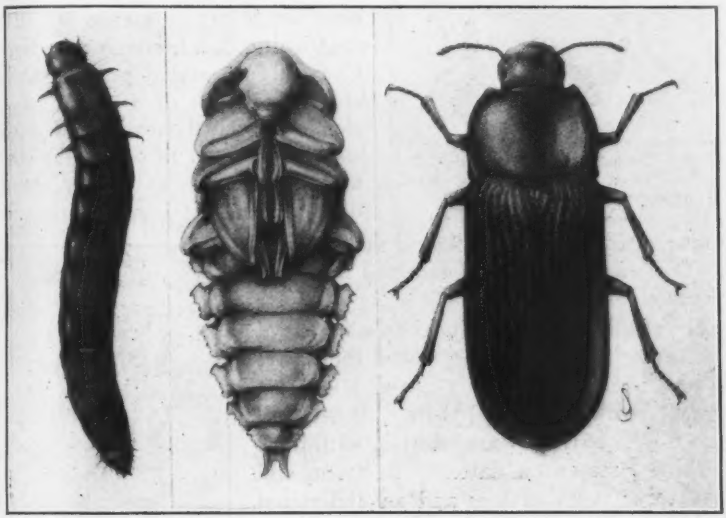

FIG. 35.—The dark mealworm: *a*, Full-grown larva; *b*, pupa; *c*, adult beetle. Distinguished from the yellow mealworm by the dark brown color of the larva and the dull, not shiny appearance of the adult beetle. For true relative size of the larva, pupa, and adult compare with figure 34.

The cadelle often becomes well established in ear corn (fig. 38) that has first been injured by the Angoumois grain moth or by the weevils. The long slits in corn kernels shown in figure 38 are characteristic of cadelle infestation. Were it not for the fact that there is not more than one generation of this insect each year the cadelle would be one of the most serious enemies of stored grain. As it is it is probably the longest lived of the insects that attack stored grain, and frequently causes severe losses.

The white eggs are laid in clusters in the food material selected and hatch in about 10 days. When the larvæ become fully grown they seek some secluded place in which to transform to the pupa (fig. 39), frequently boring into the timbers of the bin or other re-

FIG. 36.—The cadelle: Adult beetle. The cadelle is a flattened, black beetle about one-third of an inch long.

ceptacle that holds the infested material. Both larvæ and beetles feed to some extent on other grain-infesting insects, hence are partly predacious.

SAW-TOOTHED GRAIN BEETLE.[19]

The saw-toothed grain beetle gains its name from the peculiar structure of the thorax, which bears six sawtoothlike projections on each side (fig. 40). This character is a ready means of distinguishing this beetle from others that infest stored grain. It is about one-tenth of an inch long, slender, much flattened, and dark chocolate brown in color. A cosmopolitan beetle, extremely abundant at times, it is nearly omnivorous, infesting grains, flours, meals, dried fruits, seeds, etc. Both beetle and larva are very active.

The small slender eggs hatch in a few days. The emerging larvæ do not spend their lives within a single grain but crawl about actively, feeding here and there. When full grown (fig. 40), they are whitish, with dark markings, somewhat flattened in form, and have three pairs of legs and an abdominal proleg. When ready to pupate they construct delicate cocoon-like coverings by joining together small grains or fragments of foodstuffs with a sticky secretion and within this the pupa (fig. 40) and later the adult form are assumed. Development from egg to adult may take place in 24 days in summer.

FIG. 37.—The cadelle: Larva. Commonly found crawling among grain kernels. It may appear glistening white or dull and powdered according to the material in which it is crawling. When full grown it is about three-fourths of an inch long.

SQUARE-NECKED GRAIN BEETLE.[20]

The square-necked grain beetle is closely related to the saw-toothed grain beetle, which it greatly resembles in form, size, and color. It is a flattened, oblong, polished, reddish brown beetle about one-tenth of an inch long. It differs from the saw-toothed grain beetle

[19] *Oryzaephilus surinamensis* L. [20] *Silvanus gemellatus* Duv.

by having the thorax almost square in shape and lacking the sawtoothlike projections. (Fig. 41.)

This beetle is chiefly abundant in the South, where it is found in great numbers outdoors infesting the seed pods of a great variety of plants. It is one of the most common beetles in stored corn in the South and in the cornfields is always to be found on damaged or exposed ears. The immature stages closely resemble those of the preceding species both in form and in habit. The larvæ have the bad habit of devouring the germ of the seed in which they breed. They can develop from egg to adult in about three weeks.

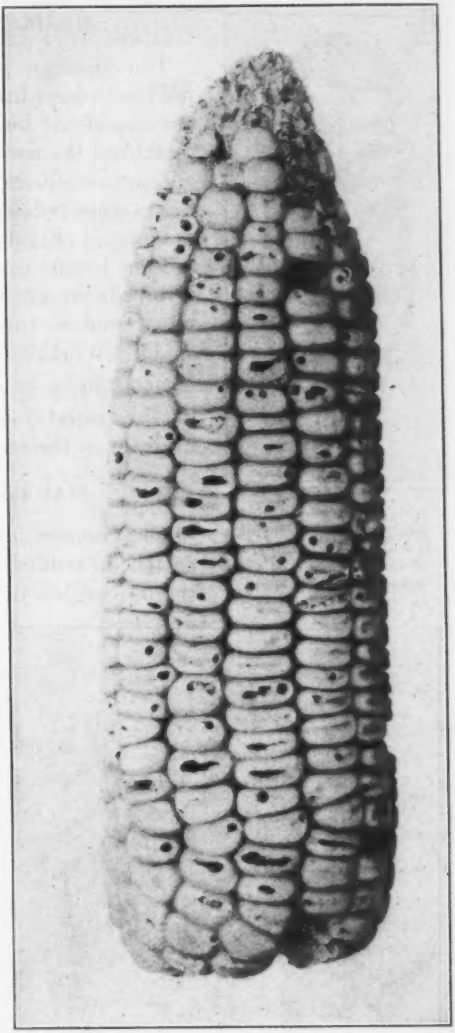

FIG. 38.—Ear of corn infested by the Angoumois grain moth (round holes in kernels) and the cadelle. The elongated slits in the kernels are characteristic of cadelle feeding and emergence. Only ear corn stored for several years will develop this evidence of cadelle attack.

FOREIGN GRAIN BEETLE.[31]

The foreign grain beetle is a small reddish brown beetle somewhat similar in appearance to the preceding species, to which it is closely related. It differs from it by being smaller and more robust. (Fig. 42.) Although of world-wide distribution, it is of little consequence as an enemy of stored grains. It is attracted to damp and moldy grains and feeds on the molds developing in such grains. It is rarely found in clean grain.

[31] *Cathartus advena* Waltl.

FIG. 39.—The cadelle: Pupa, much enlarged. The pupa is seldom seen as this stage of the cadelle's life cycle is spent in a cell made in an inaccessible place.

MEXICAN GRAIN BEETLE.[22]

The Mexican grain beetle is a highly polished, deep brown beetle about three-sixteenths of an inch long. While resembling somewhat the confused flour beetle in general appearance, it can be readily distinguished by its more polished surface and by its longer antennæ. (Fig. 43.)

This insect is common in Mexico, where it breeds in grain and grain products. It was found in this country in grain exhibits at the World's Columbian Exposition, but is not known to be permanently established in this country as yet. It may be found in grain in the extreme South.

SIAMESE GRAIN BEETLE.[23]

The Siamese grain beetle is an elongate, flattened, reddish-brown beetle slightly less than an eighth of an inch long characterized

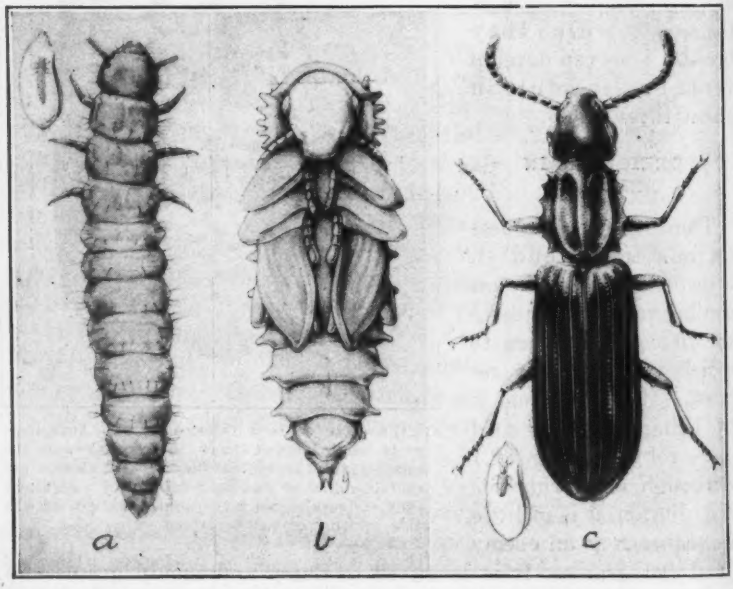

FIG. 40.—The sawtoothed grain beetle: *a*, Well-grown larva, with kernel of wheat to show its relative size; *b*, pupa; *c*, adult beetle with kernel of wheat to show its relative size. The adult beetle, about one-tenth of an inch in length, can be easily recognized by the six toothlike projections on the sides of the thorax.

[22] *Pharaxonotha kirschi* Reitt. [23] *Lophocateres pusillus* Klug.

by the much flattened margins of the thorax and wing covers (fig. 44).

First appearing in exhibits of rice and cereals from Siam, Liberia, and Ceylon at the World's Columbian Exposition, it has since been reported as injurious to stored grain and grain products in South Carolina and Texas. It is likely to be found in seaport towns and in the Southern States, but as yet it is not abundant or widespread.

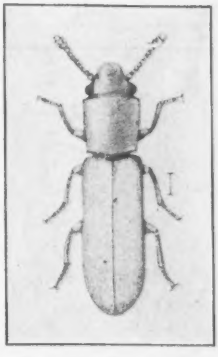

FIG. 41.—The square-necked grain beetle. (Chittenden.)

FLAT GRAIN BEETLE.[24]

The flat grain beetle is a small, flattened, oblong, reddish-brown beetle about one-sixteenth of an inch long, with elongate antennæ somewhat longer than half the length of its body. (Fig. 45.) It is readily distinguished because it is the smallest beetle commonly found in stored grain in this country. It is cosmopolitan in distribution, is very generally found in stored corn in the South, and is often screened from wheat shipments. Little is known of its habits or of its early stages, though it is thought to be a scavenger or predacious on other insects. The full-grown larvæ form cocoons of a gelatinous substance to which food particles adhere. While it is present sometimes in unbelievable numbers in grain shipments, it appears to do little damage to whole grains. The larvæ have been found destroying the germ in kernels of wheat.

FIG. 42.—The foreign grain beetle. (Chittenden.)

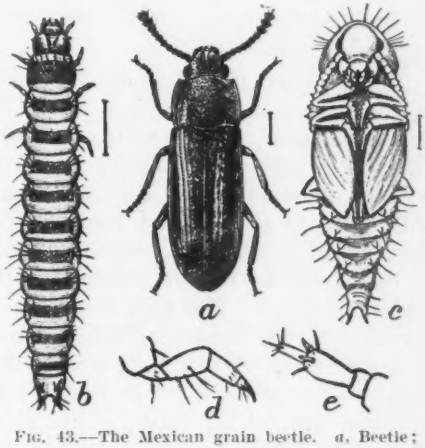

FIG. 43.—The Mexican grain beetle. *a*, Beetle; *b*, larva; *c*, pupa; *d*, leg of larva; *e*, antenna of larva. *a*, *b*, *c*, Much enlarged; *d*, *e*, more enlarged.

[24] *Cryptolestes pusillus* Schon.

CONFUSED FLOUR BEETLE.[25]

The confused flour beetle (fig. 46) is a shiny, reddish-brown beetle about one-sixth of an inch long, flattened and oval in form, with head and upper parts of thorax densely covered with minute punctures and with wing covers ridged lengthwise and sparsely punctured between the ridges. It is generally distributed over the world and is very abundant in all parts of this country. It is known as one of the flour beetles owing to its frequent occurrence in flour. It is a general feeder on starchy foods and is probably the worst insect pest of prepared cereal foods. It is constantly found in granaries, mills, and storehouses, and grain shipments.

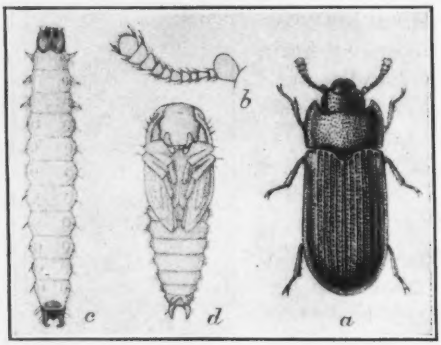

FIG. 44.—The Siamese grain beetle. *a*, Beetle; *b*, antenna of same; *c*, larva; *d*, pupa. *a*, *c*, *d*, About ten times natural size; *b*, greatly enlarged.

The minute white eggs of this beetle are laid in the cracks and crevices of bins, barrels, boxes, or other containers of the foodstuffs attacked by this insect. They are covered with a sticky secretion so that they become covered with flour, meal, etc., and readily adhere to the sides of sacks, boxes, and other containers so that fresh material placed in them is rapidly infested. The eggs hatch into small wormlike larvæ, slender, cylindrical, and wiry in appearance. When fully grown they are about three-sixteenths of an inch long, and in color are white, tinged with yellowish. These larvæ feed on flour or other material such as grain dust and the broken surfaces of grain kernels. When full grown they transform to small naked pupæ. At first white, the pupæ gradually change to yellow and then brown, and shortly afterwards transform to beetles. The period from egg to adult in summer is about four weeks under most favorable weather conditions, though the

FIG. 45.—Adult of the flat grain beetle, showing characteristic long antennæ. Not more than one-sixteenth of an inch long. This beetle is one of the very smallest found in grain shipments.

[25] *Tribolium confusum* Duv.

life cycle is greatly prolonged by cold weather, as is true of all grain pests.

RUST-RED FLOUR BEETLE.[26]

The rust-red flour beetle is almost identical in appearance with the preceding species, to which it is closely related. It can be distinguished from the confused flour beetle only with the aid of a magnifying glass. The segments of the antennæ of the confused flour beetle increase in size gradually from the base to the tip, while in the rust-red flour beetle the last few segments of the antennæ are abruptly much larger than the preceding ones, giving the antennæ the appearance of being suddenly enlarged at the tip. In addition, the margins of the head of the confused flour beetle are expanded and notched at the eyes, while the margins of the head of this species are nearly continuous at the eyes. The differences between the two species are clearly shown in figure 46, *e* and *f*.

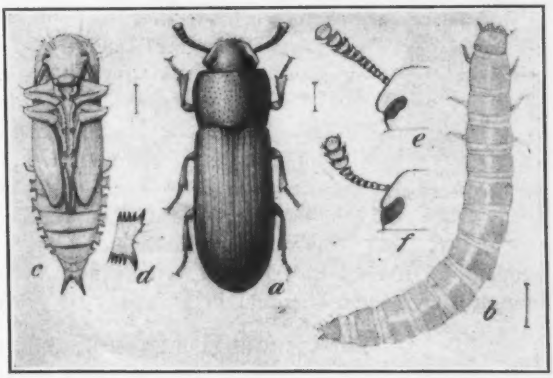

FIG. 46.—The confused flour beetle, the commonest insect recovered from grain shipments. It is about one-sixth of an inch long. *a*, Beetle; *b*, larva; *c*, pupa; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle, showing antenna; *f*, same of the rust-red flour beetle. (Chittenden.)

This insect is similar to the confused flour beetle in feeding and breeding habits, and it is impossible to distinguish between the early stages of the two insects. Although cosmopolitan in distribution, it is found more commonly in the South, where it causes very serious damage to grain products. In addition to the actual damage caused by its feeding activities, serious losses are caused by the nauseous smell and taste that it imparts to the material it infests. Like the confused flour beetle, the rust-red flour beetle is primarily a pest of milled products, and while present in grain shipments it confines its attack in these to grain dust and the surface of broken grains, hence is not a primary pest of commercial shipments.

LONG-HEADED FLOUR BEETLE.[27]

The long-headed flour beetle is a slender, flattened beetle, slightly less than an eighth of an inch long, somewhat similar in form to the

[26] *Tribolium ferrugineum* Fab.

[27] *Latheticus oryzae* Waterh. A closely related species, *Latheticus prosopsis* Chittn., is shown in figure 48.

confused flour beetle but pale yellow and further differentiated by the peculiarly shaped antennæ shown in figure 47 and by the minute canthus behind each eye. It has been reported from most parts of the world infesting wheat, rice, corn, barley, rye, flour, etc. It was first recognized in this country about 13 years ago from specimens taken in Texas. It is not known to be very widely distributed in the United States but is likely to be found in mills and granaries in the South.

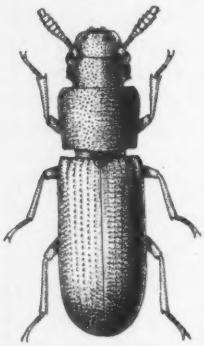

FIG. 47.—Long-headed flour beetle. (Chittenden.)

SLENDER-HORNED FLOUR BEETLE.[28]

The slender-horned flour beetle owes its name to the peculiar structure of the mandibles or jaws of the male, which are armed with a pair of slender incurved horns as shown in figure 49. The beetle is about one-eighth of an inch long, flattened and brownish, closely resembling the other flour beetles in appearance but easily distinguished by the peculiar structure of the jaws. It is distributed over the world and of frequent occurrence in the Southern States. It prefers to feed in flour and meal, but is found in a variety of grains.

BROAD-HORNED FLOUR BEETLE.[29]

The broad-horned flour beetle is closely related to the preceding species and is of similar form and appearance. It may be distinguished from it by the shape of the horns with which the mandibles or jaws of the males are armed. In this species (fig. 50) the horns are broad and stout in contrast to the slender incurved horns of the preceding species. Its habits are similar to those of the slender-horned flour beetle, and it is often found in seaport towns in shipments of grain and grain products.

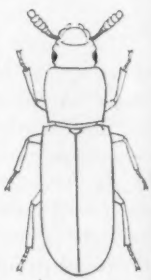

FIG. 48.—*Lathetieus prosopis.* (Chittenden.)

SMALL-EYED FLOUR BEETLE.[30]

The small-eyed flour beetle (fig. 51) is the smallest of the so-called flour beetles that infest grain and grain products in this country. It is a tiny, flattened, shiny, reddish-brown beetle, somewhat oblong in form and measuring about one-twelfth of an inch in length. It occurs throughout the world and is widely distributed in this country. It prefers ground products in which to breed, but is not infrequently found in stored grains.

[28] *Gnathocerus maxillosus* Fab. [29] *Gnathocerus cornutus* Fab. [30] *Palorus ratzeburgi* Wissm.

A closely related species[31] more common in Europe but occasionally found in this country is very similar in appearance and habits to the small-eyed flour beetle.

TOBACCO BEETLE.[32]

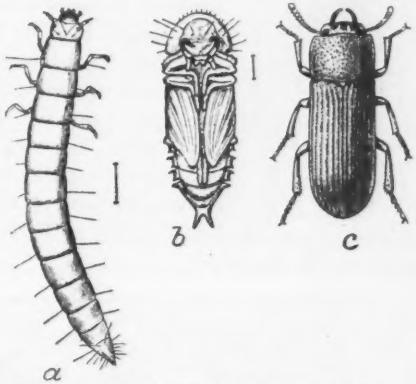

FIG. 49.—The slender-horned flour beetle: *a*, Larva; *b*, pupa; *c*, beetle. (Chittenden.)

The tobacco beetle is a small, robust, oval, reddish-yellow or brownish red beetle, with head bent down nearly at right angles to the body, giving the beetle a humped appearance when viewed from the side as shown in figure 52. It varies in size, but is usually about one-tenth of an inch long. It is found in all temperate, subtropical, and tropical regions and infests tobacco and many other stored products. It breeds in a variety of seeds and may occasionally be found attacking grains left long in storage in original sacks.

DRUG-STORE BEETLE.[33]

The drug-store beetle is very similar in appearance to the tobacco beetle, to which it is closely allied, but differs from it by being more elongate in proportion and in having the wing covers distinctly striated. It is about one-tenth of an inch long. It is cylindrical and uniform light brown; its body is covered with a fine silky pubescence. (See fig. 54.) The larva or grub is very much less hairy than that of the cigarette or tobacco beetle, as a comparison of figures 53 and 55 will show. It is known as the drug-store beetle from its habits of feeding on almost all drugs found in pharmacies. It is a very general feeder, attacking a great variety of stored foods, seeds, and other materials, and has been said to "eat anything except cast iron." It is frequently found in storehouses and granaries in all parts of the world.

FIG. 50.—The broad-horned flour beetle. (Chittenden.)

The eggs of this beetle are laid in almost any dry organic substance. The small white grubs emerging from the eggs tunnel through these substances and when full grown pupate in small cocoons. The entire life cycle may be passed in less than two months.

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[31] *P. depressus* Fab. [32] *Lasioderma serricorne* Fab. [33] *Sitodrepa panicea* L.

FIG. 51.—The small-eyed flour beetle. (Chittenden.)

BLACK CARPET BEETLE.[24]

The black carpet beetle is a small oval beetle between two-sixteenths and three-sixteenths of an inch long. The head and thorax are black, but the wing covers may be either black or dark reddish brown, and clothed with short hairs. Its legs and antennæ are dark yellowish in color. The larva is very characteristic and can be readily recognized. It is reddish or golden brown, clothed with short scale-like appressed hairs and provided with a tuft of long hairs at the end of the body, as shown in figure 56.

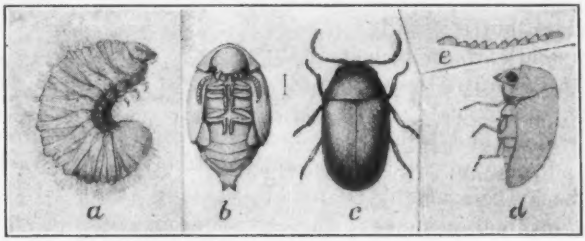

FIG. 52.—The tobacco beetle never attacks grain unless it has been stored for long periods. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden.)

As the name indicates, this insect injures carpets, but in addition it is known to breed in grains and cereals, both whole and ground. The larval stages develop very slowly, and there is but one generation each year. The adults appear in greatest numbers during the spring and early summer. It occurs in Europe and Asia and has been reported from all parts of this country. It is of very common occurrence in houses.

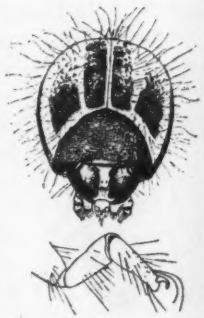

FIG. 53.—The tobacco beetle: Head and leg of larva. (Chittenden.)

LARGER CABINET BEETLE.[25]

The larger cabinet beetle is a small, oval beetle about one-eighth of an inch long, its ground color black mottled with reddish brown, covered with gray and light brown scale-like hairs forming a distinct pattern on the wing covers. The larva somewhat resem-

[24] *Attagenus piceus* Oliv. [25] *Trogoderma tarsale* Melsh.

bles that of the black carpet beetle in appearance. It is about one-eighth of an inch long, reddish brown above and whitish beneath, with body covered with short yellowish brown hairs and with a tuft of short hairs at the tail end. (See fig. 57.) It is well known for its habit of breeding in dead insects and animal substances and is not infrequently found living in grain, flaxseed, castor beans, pumpkin seed, etc. It often becomes a nuisance in laboratories by attacking sample lots of corn, wheat, etc.

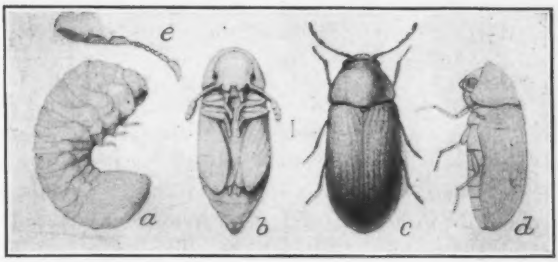

FIG. 54.—The drug-store beetle never attacks grain unless it is stored for long periods unmolested. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden.)

SMALL CABINET BEETLE.[36]

The small cabinet beetle is somewhat similar in appearance to the larger cabinet beetle but smaller and of different color. It varies in length from one-sixteenth to two-sixteenths of an inch, and is black with yellowish white scales that form a broad band across the back and give the body a mottled appearance. The habits of the adult and early stages of this insect are similar to those of the larger cabinet beetle. It is occasionally found in flour mills and granaries, where it infests grain and grain products.

FIG. 55.—The drug-store beetle: Head and leg of larva. (Chittenden.)

MUSEUM BEETLE.[37]

The museum beetle is closely allied to the preceding beetle and resembles it in size and form. Its body is black, covered with yellowish and whitish scales, giving it a spotted appearance. It is a small plump beetle varying in size from one-sixteenth to one-eighth of an inch in length. The larvæ are small active hairy grubs with habits similar to those of the two preceding species. They are occasionally found in grains, both whole and ground, but do not cause noticeable damage.

TWO-BANDED FUNGUS BEETLE.[38]

The two-banded fungus beetle is a handsome little elongate-oval beetle slightly less than an eighth of an inch long. It is red-brown with two broad black bands across the wing covers. Its character-

[36] *Anthrenus verbasci* L. [37] *Anthrenus museorum* L. [38] *Alphitophagus bifasciatus* Say.

istic color pattern is shown in fig. 58. It is distributed over the world and is in general a feeder on fungi and molds, being a scavenger in refuse grain and grain products, decaying vegetable matter, etc. It is frequently found around mills and storehouses where waste material is allowed to accumulate. The larvæ have been bred from moist cornmeal and in spoiled cereals. The insect is often found in the holds of grain ships in wet or damaged grain.

BLACK FUNGUS BEETLE.[39]

The black fungus beetle (fig. 59) resembles the mealworm beetles in form and color but is considerably smaller. It is black or a very dark reddish brown and measures from three-sixteenths to four-sixteenths of an inch in length. The larva (fig. 59, *a*) is yellowish

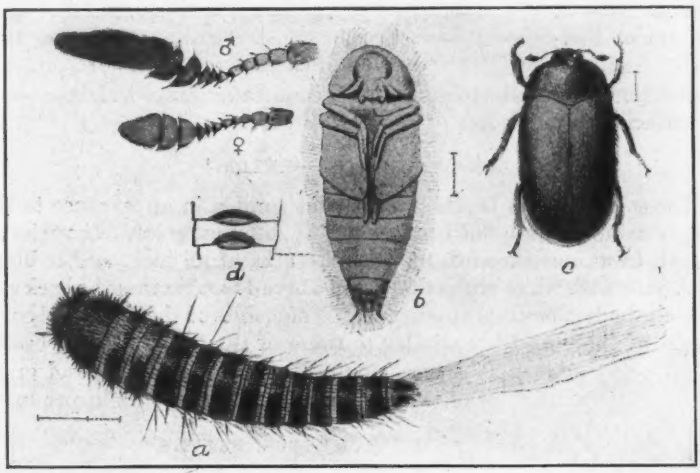

FIG. 56.—The black carpet beetle is chiefly a pest of sample grains, or found in grain dust about elevators or storage bins. *a*, Larva; *b*, pupa; *c*, beetle; *d*, dorsal abdominal segments of pupa; ♂, antenna of male beetle; ♀, antenna of female beetle. (Howard.)

brown and is very similar in form and appearance to young larvæ of the mealworms. This beetle is often found in the same situations as the red-banded fungus beetle. It breeds in damp moldy grain but causes no injury to grain that is sound and dry.

CORN SAP-BEETLE.[40]

The corn sap-beetle may be readily recognized by its peculiar wing covers, which are short and truncate, leaving the tip of the abdomen exposed as shown in figure 60. It is a small dark brown beetle with lighter colored wing covers, oblong-ovoid in shape, and varying in length from one-tenth to one-eighth of an inch. It normally feeds in

[39] *Alphitobius piceus* Oliv. [40] *Carpophilus dimidiatus* Fab.

rotting and decaying fruit and vegetation and in the sap exuding from injured plants. It is quite numerous in cornfields in the South, swarming over the damaged ears and feeding and breeding in the decaying kernels. It is attracted to damp and decaying grain but is seldom found in grain that is clean and dry.[41]

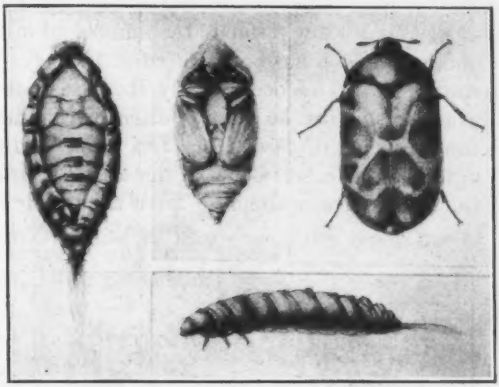

FIG. 57.—The larger cabinet beetle: At left, pupa within larval skin; in center, pupa; at right, beetle; below, well-grown larva.

A closely related beetle[42] that has been introduced from abroad and is becoming more and more abundant is similar in form to the corn sap-beetle, but is slightly larger and is a uniform, shiny, dark brown all over. Its habits are very similar to those of the preceding species.

BOOK-LICE OR PSOCIDS.[43]

Book-lice or psocids are minute, pale, soft-bodied, louse-like insects, about one thirty-second of an inch long, with long, slender antennæ, differing greatly in appearance from other grain-infesting insects. (See fig. 61.) They may be whitish, almost transparent, or quite dark.

FIG. 58.—The two-banded fungus beetle. Adult.

Psocids are of very common occurrence and may be found in nearly any situation. They are almost omnivorous, feeding on any animal or vegetable matter. They are frequently found in grain, but while they have jaws and are capable of feeding upon solid materials, they may be disregarded as pests of grain. They are frequently very abundant in grain and are here recorded because of the curiosity of persons to know what they are. For further information regarding them see Farmers' Bulletin 1104, "Book-Lice or Psocids."

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[41] *Carpophilus pallipennis* Say, a purely flower-infesting beetle, has been occasionally reported as infesting stored corn. In these cases large specimens of the corn sap-beetle which closely resemble this species were probably mistaken for it.

[42] *Carpophilus humeralis* Murray.

[43] *Troctes divinatoria* Fab. *et al.*

MITES.[44]

Mites are pale-colored, soft-bodied creatures provided with numerous long hairs, as illustrated in figure 62. They are microscopic in size. As a low estimate the number of mites that may be found on one square inch has been placed at 100,000. They are often found in stored grain and occasionally increase with such rapidity that the grain seems to be fairly alive with them. During heavy infestations their cast skins and dead bodies accumulate in fluffy light brown masses beneath the sacks of grain. If these accumulations are on a warehouse floor they roll up into piles which are blown about with each gust of wind. No other group of pests in

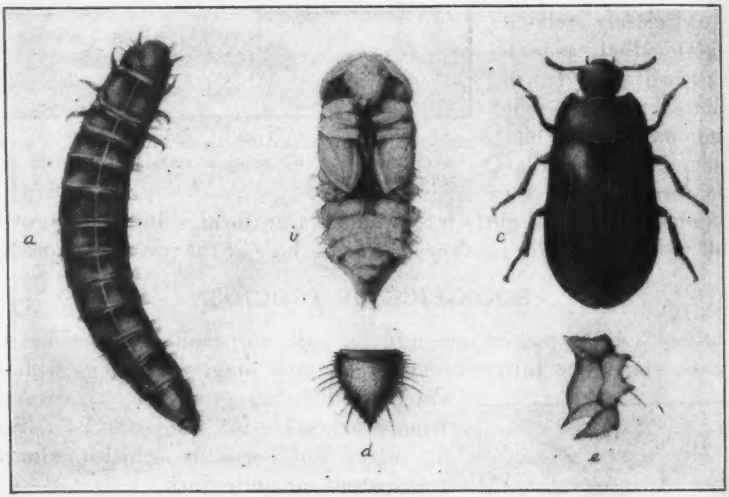

FIG. 59.—The black fungus beetle: *a*, Larva; *b*, pupa; *c*, adult; *d*, caudal segment of larva (Schiödte); *e*, lateral plate of pupa (Schiödte).

grain will produce these masses. When present in large numbers they promote "sweating," impart a disagreeable odor to the grain, and may cause damage by their feeding. Fortunately the mites that attack grain are themselves preyed upon by predacious mites which usually become abundant enough to kill the grain mites in a comparatively short time. If they do not, the screening and fanning of grain will usually reduce mite infestations to a point where no injury takes place.

PARASITES OF GRAIN PESTS.

Grain in bulk is often seen swarming with small black wasplike insects of a size and appearance shown in figure 63. These do

[44] *Tyroglyphus* spp.

not cause injury to grain. On the contrary, they are beneficial, as they are attacking and killing the grain weevils and grain moths. While parasites kill a large number of grain insects, they unfortunately can not be considered of great importance from the standpoint of grain protection, for by the time the grain insects have been controlled by parasites the grain itself has become very badly damaged. For this reason the appearance of a large number of parasites in grain cars or elevators should be disregarded and the grain treated as though parasites were not present.

FIG. 60.—The corn sap-beetle. Adult.

Grain dealers frequently find a small threadlike white worm [45] (fig. 64) about three-quarters of an inch long in grain dust beneath sacks or in the bottoms of bins. This is the larva of a small black fly to be found crawling upon windows of granaries and flour mills. Because of this habit it is called the window-pane fly. Its threadlike larva does no harm to grain but is predacious upon the larvæ of grain pests and clothes moths. It is not abundant enough to be of value in protecting grain.

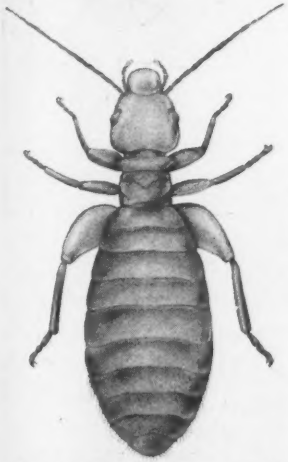

FIG. 61.—Book-louse or psocid.

HOW GRAIN BECOMES INFESTED.

Grain may become infested in a number of ways. It is never possible to settle satisfactorily litigation over responsibility for insect damage to grain without a thorough knowledge of the history of the particular grain shipment involved.

Several of the worst insect pests of grain, notably the Angoumois grain moth and the rice or black weevil, fly to the grain fields from near-by cribs and begin their attack upon the maturing grain. In the case of wheat and similar small grains, the eggs of the insect are laid directly upon the heads of grain. In the case of corn the insects can infest only those kernels that are exposed because of poorly de-

[45] *Scenopinus fenestralis* L.

veloped or damaged shuck covering. In cornfields, especially in the South, where insect infestation occurring in the field is most severe, there are a sufficiently large number of exposed kernels to bring about slight, though widespread, infestation.

It is probably true that in well-grown crops of corn the percentage of kernels infested before the crop is ready for harvest is very small, and throughout the Middle and Northern States is a negligible factor. In the Gulf Coast States, especially in upland fields, the infestation often is very severe. In the case of wheat, grown particularly along the Ohio River, in southern New Jersey, in Pennsylvania,

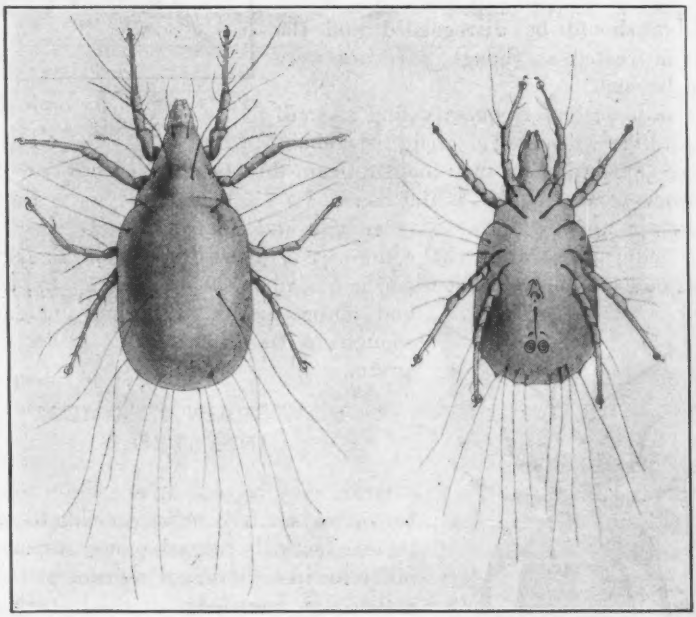

FIG. 62.—Grain mites. (Howard.)

Maryland, Delaware, Virginia, and southward, the field infestation may be much more general than is now believed. Newly thrashed wheat from Maryland arriving in September on the Baltimore market showed infestation ranging up to 6 per cent. While these infestations occurring in the grain before it is harvested are usually unavoidable, they are of great importance as "leaven" which in storage may result in a general infestation of an entire crop, in heating, and in much damage.

After grain has been harvested it is often stored in bins, storehouses, or barns that have held, or still hold, infested grain and which

have not been thoroughly cleaned. Wooden bins and wooden partitions in grain storehouses and in the holds of grain-carrying ships become the nesting places for an incredibly large number of grain pests. Certain of these can and do bore into the softer portions of the partitions and timbers that are used over and over again as dunnage, and the excavations they make serve as hiding places not only for themselves but all other species associated with them. Unless such bins and partitions are thoroughly disinfected by fumigants, these hidden insects can not be killed. The mere spraying of contact insecticides upon the walls will not reach them. If uninfested grain is placed in such bins, it naturally will become infested by the insects coming from the bin walls.

FIG. 63.—Hymenopterous parasite of grain pests. Adult parasite resting upon a kernel of wheat. These tiny gnat-like insects are beneficial but their help usually comes too late to prevent damage to the crop in which they are most abundant.

FIG. 64.—Larva of a kind of fly that preys upon grain beetles and mites. This white threadlike worm is sometimes found in grain dust and attains a length of about three-fourths of an inch; while interesting, it is of no practical value.

Likewise, uninfested grain should not be placed for shipment in sacks previously used for grain storage, for, as shown in figure 32, these old sacks often harbor insects unless they have been treated by heat or fumigation. Certain extensive and costly infestations have been traced directly to the use of secondhand untreated grain sacks.

Grain stored in the open or in poorly constructed cribs or bins may become infested by insects flying in from outside sources.

HOW TO PREVENT PRIMARY INFESTATION.

Infestation of grain in the field can not be entirely prevented, but by proper precautions it can be reduced to a minimum. The first gen-

eration of insects in the maturing grain is usually small, and if the grain is cut as soon as ripe, thrashed as soon as dry, and then placed in storage in clean, deep bins the damage from this source will be very slight. It is when the grain is left in the field long after it is ripe that serious infestation results, for the insects increase in one or two generations to enormous numbers. In the case of corn in the field, only those ears that are damaged or through poor shuck development have kernels exposed are subject to the attack of grain insects. Farmers should therefore grow a variety of corn that develops a long tight shuck.

Newly harvested small grains should not be stored unthrashed for any length of time. as in this condition they are very susceptible to infestation. If promptly thrashed and stored in deep bins, only a thin layer on top of the bin is likely to become infested. Corn may be stored in the shuck if the husk is long and tight and fully covers the tip, but all ears with loose, broken, short, or damaged husks should be shucked and stored separately.

Clean grain should never be stored in old bins, granaries, or storehouses until they have been thoroughly cleaned and freed from the accumulations of waste grain and other materials harboring grain insects. Timbers in bins, granaries, or holds of ships that have become infested with grain insects should be destroyed or treated before being used again. Steel or concrete bins are highly desirable owing to the ease with which they are cleaned.

Bags of all kinds that have previously held grain should not be allowed in granaries or warehouses or be refilled until they have been sterilized by heat or otherwise freed from insects. The use of tight cribs will keep the grain free from infestation by insects that might fly in from the outside.

THE TREATMENT OF INFESTED GRAINS.

Insects infesting stored grain can be destroyed by the use of heat, or by fumigation with poisonous gases. These remedial measures are mentioned only briefly in this bulletin.

HEAT.

A temperature of 120° to 130° F., maintained for a short time, will kill all stages of grain-infesting insects, without injuring the germinating quality of the grain. Owing to the difficulty of subjecting the grain to such a temperature this method of control is used chiefly by millers and large grain dealers who are equipped with commercial driers suitable for the purpose.

FUMIGATION.

Carbon disulphid, carbon tetrachlorid, and hydrocyanic-acid gas are the fumigants in most common use to-day for treating infested grain. Of these, carbon disulphid is the best for treating grain in bulk. It is heavier than air and if applied at the top of a gas-tight bin of grain will penetrate down through the grain, killing the insects without injury to the grain, providing it is dry. It has the one great disadvantage of being inflammable and will explode if fire in any form is brought near it. It is in general use on farms for the protection of grain in cribs (see U. S. Department of Agriculture, Farmers' Bulletins 799 and 1029.)

Carbon tetrachlorid is not as effective as carbon disulphid and costs more. For these reasons it is not in such general use. It has the great advantage of removing the fire hazard, as it is not inflammable and does not explode in presence or fire.

Hydrocyanic-acid gas is not of value in fumigating bulks of grain. When grain is stored in sacks in warehouses, heavy doses of this gas will control grain pests. This method of fumigation is discussed in Department Bulletin 872.

Fumigation with chloropicrin is not in general use at present.

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STORED-GRAIN PESTS

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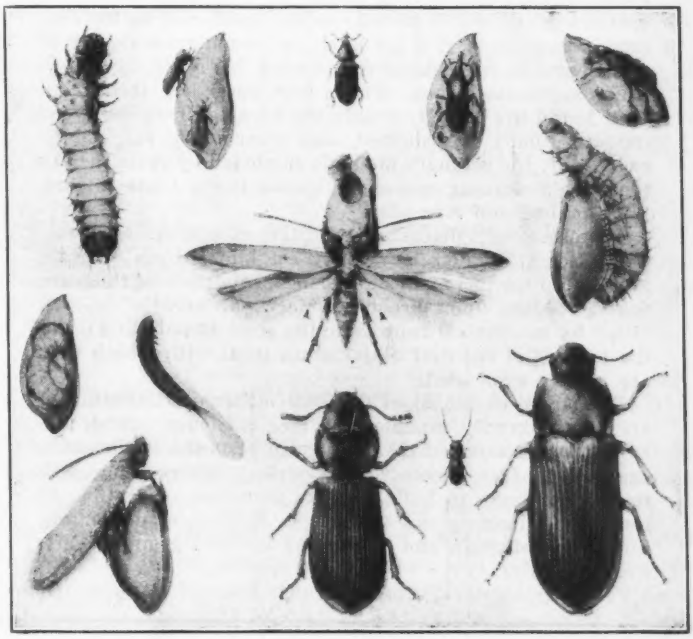

UNITED STATES
DEPARTMENT OF AGRICULTURE

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MOST of the damage done by insects to grain in storage and shipments is due to four species. These are the granary weevil, the rice or black weevil, the lesser grain borer or Australian weevil, and the Angoumois grain moth. Others of the 40 species or groups of species described in this bulletin can cause great damage to grain if storage conditions are unusually favorable for their increase. Yet if grain in the unbroken kernel remains unaffected by the four insects mentioned, it is not likely, in commercial storage or shipments, to be sufficiently affected by other insects to cause appreciable loss. These four pests live throughout their larval life entirely within the kernel, where they feed unseen, usually unsuspected, and where they can not be reached by the ordinary methods employed by grain men in their grain-cleaning operations known to the trade as moving, fanning, and screening.

The other pests discussed, with few exceptions, are "surface feeders." Their larvæ may eat into kernels of grain and lie hidden there, yet the greater proportion of them are found feeding upon broken surfaces of kernels exposed either by mechanical injuries to the grain in handling or by the feeding of the four major grain pests with which they are usually associated.

The larvæ, or grubs, of the four major pests mentioned are not ordinarily capable of a free existence outside the kernel but the larvæ of the other grain pests are, in the main, capable of free locomotion, crawling where they will throughout grain in bulk, and are therefore susceptible to removal by fanning and screening. Methods of preventing infestation of grain and of treating infested grain are discussed briefly.

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STORED-GRAIN PESTS.

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POPULAR CLASSIFICATION OF GRAIN PESTS.

Since the establishment of the Federal standards for grain under the provisions of the Grain Standards act, Federal grain supervisors and federally licensed grain inspectors are required to identify the various species of "live weevils and other insects injurious to stored grain" which may be present in the grain, and uniform names for grain insects should be used. Such uniform terminology will indicate definitely to all interested persons, including shipper, purchaser, and elevator operator, the exact nature of the insect found. Of the four major pests, the granary weevil, the rice or black weevil, and the lesser grain borer may be well called "grain weevils." The fourth of the major pests, the Angoumois grain moth, so destructive to wheat and corn, may be called "grain moth." Other insects likely to be found in any lot of grain may be called simply "beetles," "moths," and "mealworms," for their presence usually does not indi-

cate a condition likely to affect the trade, provided that after the grain has reached the elevator it is screened and fanned to remove these insects.

The writers have divided the insects discussed in this bulletin into grain weevils, grain borers, grain moths, flour moths, mealworms, grain and flour beetles, psocids, and mites. In some respects this is not a satisfactory grouping, especially for the insects listed as "grain and flour beetles," but it has the advantage of definitely placing the most serious insects troublesome in bulk grain.

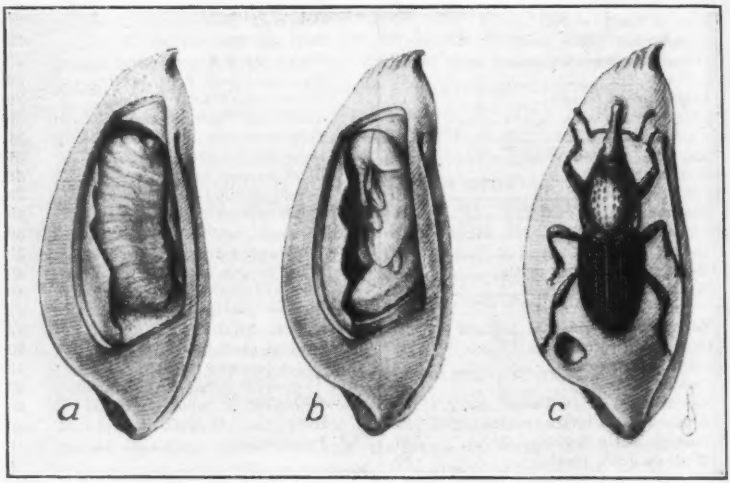

FIG. 1.—Life stages of the granary weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult. Note hole in kernel made by the adult in order to leave the seed, and hole that it is eating into the kernel for the purpose of laying eggs. This weevil closely resembles the rice weevil but has no papery wings beneath its wing covers, and the dot-like punctures on the back behind its head are elongate rather than round.

GRAIN WEEVILS.

Of the four true weevils that attack grain in the United States only two are of primary importance at present, the granary weevil and the rice or black weevil. The broad-nosed grain weevil and the coffee-bean weevil are of minor importance except locally. These four weevils have an elongated beak or snout, as shown in the illustrations, though the beak of the coffee-bean weevil is greatly reduced.

GRANARY WEEVIL.[1]

The granary weevil (fig. 1) is a small, moderately polished, chestnut brown or blackish beetle with head prolonged into a long slender snout at the end of which are a pair of stout mandibles or jaws. It is

[1] *Sitophilus granarius* L.

not more than three-sixteenths of an inch long, and often smaller. It has no wings under its wing covers and the thorax is well marked with longitudinal punctures, two characteristics that distinguish it from the closely related rice weevil, with which it is often found associated. The well-grown footless whitish grub or larva and the pupa are shown at *a* and *b*, respectively, in figure 1. The granary weevil is one of the oldest known insect pests, is a universal feeder upon grains, and is cosmopolitan, having been carried by commerce to all parts of the world. It prefers a temperate climate and is more frequently found in the Northern States than in the South.

Both adult and larva feed voraciously on a great variety of grains. The adult weevils may live for 10 or more months, and during this period each female may lay from 200 to 300 eggs. Before laying her eggs the female bores a small hole in the grain berry with her snout. When this is made she turns about and lays in it an egg, which she then covers with a gelatinous fluid which seals the hole. The small white fleshy and legless grubs that hatch from the eggs burrow about inside the kernel. When full grown, the grub transforms to the pupa stage and then into the adult weevil. In warm summer weather the granary weevil requires about four weeks to pass through the egg, larva, and pupa stages and emerge as an adult of the succeeding generation. The period of development may be prolonged greatly by cold weather.

RICE OR BLACK WEEVIL.[2]

The rice or black weevil is a small snout-beetle which varies considerably in size but rarely measures more than one-eighth of an inch in length (figs. 2 and 3). It varies in color from reddish brown to nearly black and is usually marked on the back with four light reddish or yellowish spots. It closely resembles the granary weevil in form, but it has well-developed wings beneath its wing covers, differs in color and markings, and has the thorax densely pitted with round, instead of longitudinal punctures. Figure 2 gives a good impression of the appearance of the rice weevil and its earlier stages.

This weevil has been known from early times. It is found in all parts of the world where grain is used and is one of the very worst pests in stored grain. It is particularly abundant in warm countries, where it breeds continuously and rapidly destroys all unprotected grain. Throughout the South it causes tremendous losses to corn (figs. 4, 5, 6, and 7) and is the commonest of the serious pests of commercial grain shipments.

The adult weevil lives, on an average, four or five months, each female laying between 300 and 400 eggs during this period. The

[2] *Sitophilus oryza* L.

early stages are almost identical in habit and appearance with those of the granary weevil and need not be further described. The rice

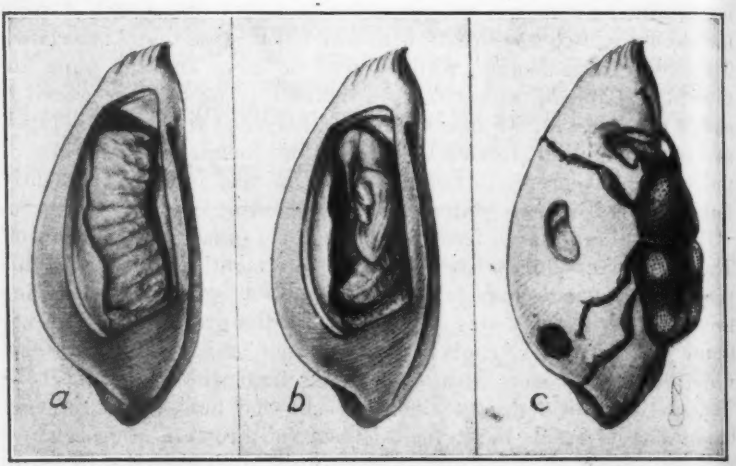

FIG. 2.—Life stages of the rice or black weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult feeding upon kernel. Note in *c* the hole in lower portion of kernel made by the adult on leaving the seed, and at two points higher up shallow holes made by the adult in feeding upon the seed after emergence. The adult weevil is at once distinguished from the granary weevil, shown in figure 1, by the four light reddish brown or yellow spots on its wing covers, by the possession of wings beneath the wing covers, and by the many rounded punctures on the back behind its head.

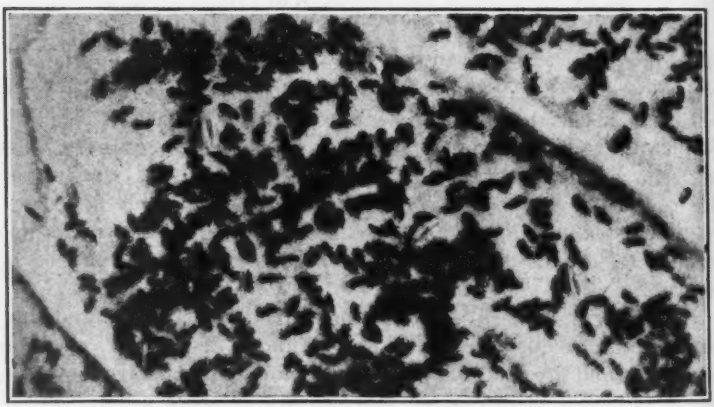

FIG. 3.—The rice or black weevil: Many adult weevils caught in the mesh of a cloth sack containing pearled barley. Compare their size with that of the barley kernels. Adult weevils when disturbed usually "play possum," but if spread upon a cloth in the sun the live ones will soon show signs of life.

weevil is a strong flier. The adults fly from granaries to the fields of grain and there start the infestation that often proves so disastrous after the grain has been harvested. During summer weather

FIG. 4.—Ear of corn with a poor, loose shuck. It is badly infested with rice or black weevils. As the adult weevils feed, they push from the kernels the chewed-up portions, frass, etc., and this material, resembling white dust, collects in larger quantities between the kernels and the shuck, or, if the ears are shucked, it falls like powder onto any object below the ear. (Back.)

FIG. 5.—An ear of corn badly damaged by rice or black weevils. This ear has been hit against a table to jar loose the powdery substance, sometimes called the farinaceous material, and so reveals the great damage done by the weevils. The kernels of the ear have been reduced to powder and shell. (Back.)

the egg, larva, and pupa stages may be passed in as few as 26 days. This period, of course, is greatly prolonged during cool or cold weather. For a further discussion of this pest see Farmers' Bulletin 1029, United States Department of Agriculture.

FIG. 6.—Kernels of corn taken from badly infested ear corn, showing how the rice or black weevils can thoroughly destroy all parts of the kernels. (Back.)

BROAD-NOSED GRAIN WEEVIL.[3]

The broad-nosed grain weevil is a small dark-brown snout-beetle slightly less than one-eighth of an inch long. In form and color it resembles the granary weevil somewhat but differs from it and other grain-infesting weevils by having a short, broad snout (see figure 8.)

This weevil is occasionally found in Georgia and South Carolina and is wide-spread in Florida, where it is a serious pest of stored grains. It is unable to breed in dry, hard, uninjured grain, but attacks soft or damaged grain, or grain that has been attacked by other grain insects. It is a strong flier, and, like the rice weevil, flies to the cornfields and infests the grain before it becomes fully hardened.

The adult weevils normally live for about five months, and during this time the females lay between 200 and 300 eggs. The small white eggs are usually laid in broken portions of the grain. They hatch in a few days, and the small, white, legless grubs feed on the softer portions of the grain until they become fully grown. They then change to a white pupal form which in a few days transforms to the

[3] *Caulophilus latinasus* Say.

adult beetle and cuts its way out of the grain. The period from egg to adult in summer is about one month.

FIG. 7.—Slip-shuck corn showing holes eaten through the shuck by the rice or black weevil. These holes make passages through which all kinds of grain pests move back and forth to bring about a more speedy destruction of the kernels. (Back.)

COFFEE-BEAN WEEVIL.[4]

The coffee-bean weevil is a very active, robust beetle from two-sixteenths to three-sixteenths of an inch long; dark brown in color, clothed with a mottled light and dark-brown pubescence. It may be easily recognized from the accompanying illustration (fig. 9).

This weevil is found in many countries and is extremely abundant in the Southern States, where it breeds in dried fruit, coffee berries, cornstalks, corn, and the seed and seed pods of an almost endless variety of plants. It is a strong flier and is frequently to be seen in the cornfields of the South on the exposed and damaged ears. It lays its eggs in the soft kernels of corn and breeding continues after the corn has been harvested and placed in storage. It does not cause much damage to corn in storage, as the corn becomes too hard to be attractive. It may, however, be very abundant locally in corn in Florida during the first three months of storage, and has been reported as completely destroying a sack of kafir seeds in Honolulu. Taking the country at large, the coffee-bean weevil is a very minor grain pest. Figure 10, *a* and *b*, shows the rather characteristic holes cut in the kernels of corn and in corn shucks by the larvæ and emerging adults.

[4] *Araecerus fasciculatus* DeG.

GRAIN BORERS.

Two species of grain borers are now established in the southern States. The *lesser grain borer* bids fair to become a very serious

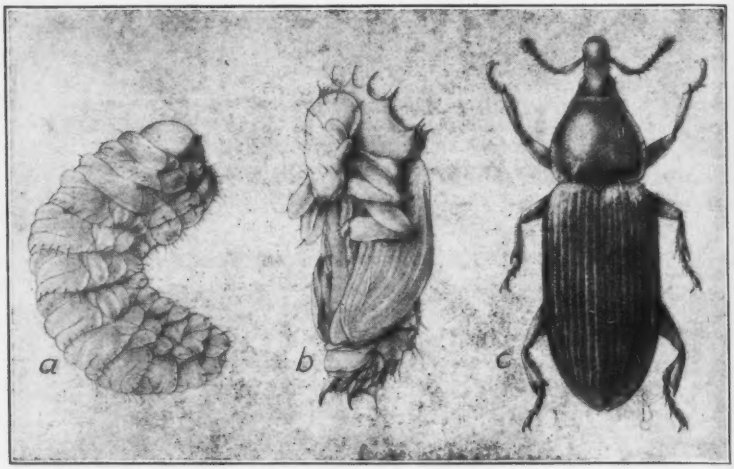

FIG. 8.—The broad-nosed grain weevil: *a*, Full-grown larva; *b*, pupa; *c*, adult weevil. This weevil is not found in northern-grown grains. It is now present in the southeastern Gulf States. The adult weevil is slightly less than one-eighth of an inch long. It is distinguished from the rice and granary weevils by its much shorter beak.

pest of grain throughout the South. The *larger grain borer* has not yet become a factor in commercial shipments of grain.

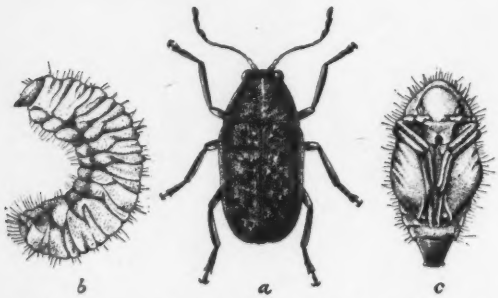

FIG. 9.—The coffee-bean weevil: *a*, Adult; *b*, well-grown larva; *c*, pupa. The adult is about three-sixteenths of an inch long, of a dark brown color covered with a light and dark brown hairiness. (Chittenden.)

LESSER GRAIN BORER.[5]

The lesser grain borer, known to many grain dealers more popularly as the "Australian wheat weevil," because of the large supplies of wheat infested by it that reached this country from Australia during the war, is one of the smallest beetles injurious to grain in this country. It appears to be steadily spreading throughout the South, and infested grain

[5] *Rhizopertha dominica* Fab.

has been found in Texas, Kansas, Oklahoma, Louisiana, Florida, and California, besides at many points of entry. It is readily distinguished from other grain pests by its slender cylindrical form and small size. It is a polished dark brown or black in color, with a

FIG. 10.—Work of the coffee-bean weevil: *a*, Holes made in corn shucks by the adult weevils eating their way out from the kernels beneath; *b*, two kernels in which larvæ of this insect have developed. Note that a single larva devours a large portion of a single kernel, which is not true of the rice weevil.

somewhat roughened surface, about one-eighth of an inch long and one thirty-second of an inch wide. Its head is large, prominent, and bent down under the thorax. The larva, pupa, and adult stages are illustrated in figure 11. It belongs to a family[6] of beetles that have

[6] Bostrychidae.

the head turned down under the thorax and are armed with powerful jaws with which they can cut directly into wood. Originally native

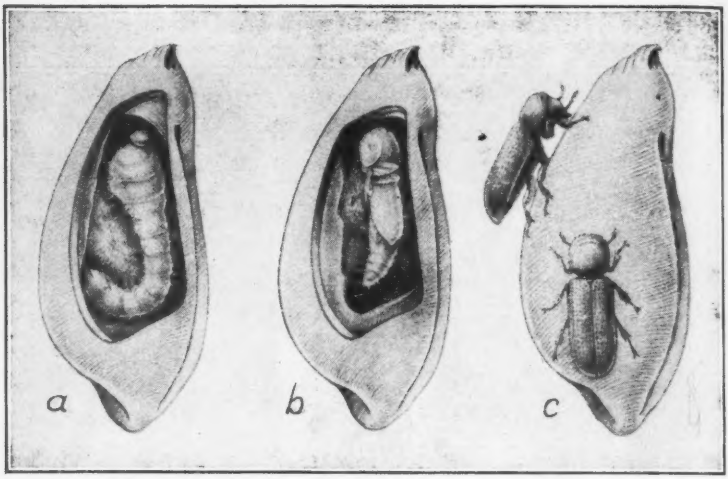

FIG. 11.—The lesser grain borer in wheat kernels: *a*, The well-grown larva; *b*, the pupa; *c*, two adult weevils. Adult borer is shiny roughened dark brown or black, about one-eighth of an inch long.

to the tropics the lesser grain borer has spread through commerce to all parts of the world.

Both beetles and larvæ cause serious damage in warm climates, attacking a great variety of grains. The destruction of which they

FIG. 12.—Kernels of wheat thoroughly riddled and devoured by the boring and feeding of the lesser grain borer and its larva. Such damaged kernels are always surrounded by much powder or flour-like material which the insects have chewed up and pushed out from the kernels.

are capable is shown by the wheat kernels of figure 12, which are literally riddled by the boring adults and their young. The females

lay from 300 to 500 eggs each, dropping them singly or in clusters in the loose grain. The eggs hatch in a few days and the small whitish grubs crawl actively about the grain, feeding on the flour produced by the boring of the beetles, or boring directly into grains that have been slightly damaged. They complete their growth within the grain, transform to white pupæ, and in time change to adult beetles which cut their way out of the grain. The period from egg to adult in summer is said to be about a month.

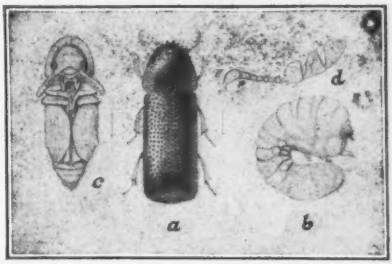

FIG. 13.—The larger grain borer: *a*, Adult insect; *b*, larva; *c*, pupa; *d*, antenna of adult. Adult borer is shiny polished dark brown, about one-sixth of an inch long. *a*, *b*, *c*, About six times natural size; *d*, highly magnified. (Chittenden.)

LARGER GRAIN BORER.[7]

The larger grain borer is a small, dark brown, elongate-cylindrical beetle about one-sixth of an inch long. As may be seen in figure 13, it is very similar in appearance to the lesser grain borer, but may be distinguished by its larger size and comparatively smooth, polished surface.

This beetle is a tropical insect not as yet widely distributed in this country. It is occasionally found infesting corn (fig. 14) in the Southern States. Its habits are similar to those of the lesser grain borer. It, also, has probably acquired its grain-feeding habits rather recently.

FIG. 14.—Kernel of corn showing work of adult of larger grain borer. The adult borers tunnel in all directions and reduce kernels to powder and shells. Enlarged. (Chittenden.)

GRAIN MOTHS.

The grain moths include only those moths capable of destroying sound, unbroken grain kernels. They are not so abundant as the flour moths, which are principally pests in broken, damaged kernels or milled products.

ANGOUMOIS GRAIN MOTH.[8]

The Angoumois grain moth is a small buff or yellowish brown moth with a wing expanse of about one-half inch. This is the moth most commonly found in infested grain in this country and is not likely to be confused with any other. It attacks all cereal grains, is found in all parts of the world, and is particularly injurious in the South, where it attacks grain both in the field and in storage.

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[7] *Dinoderus truncatus* Horn. [8] *Sitotroga cerealella* Oliv.

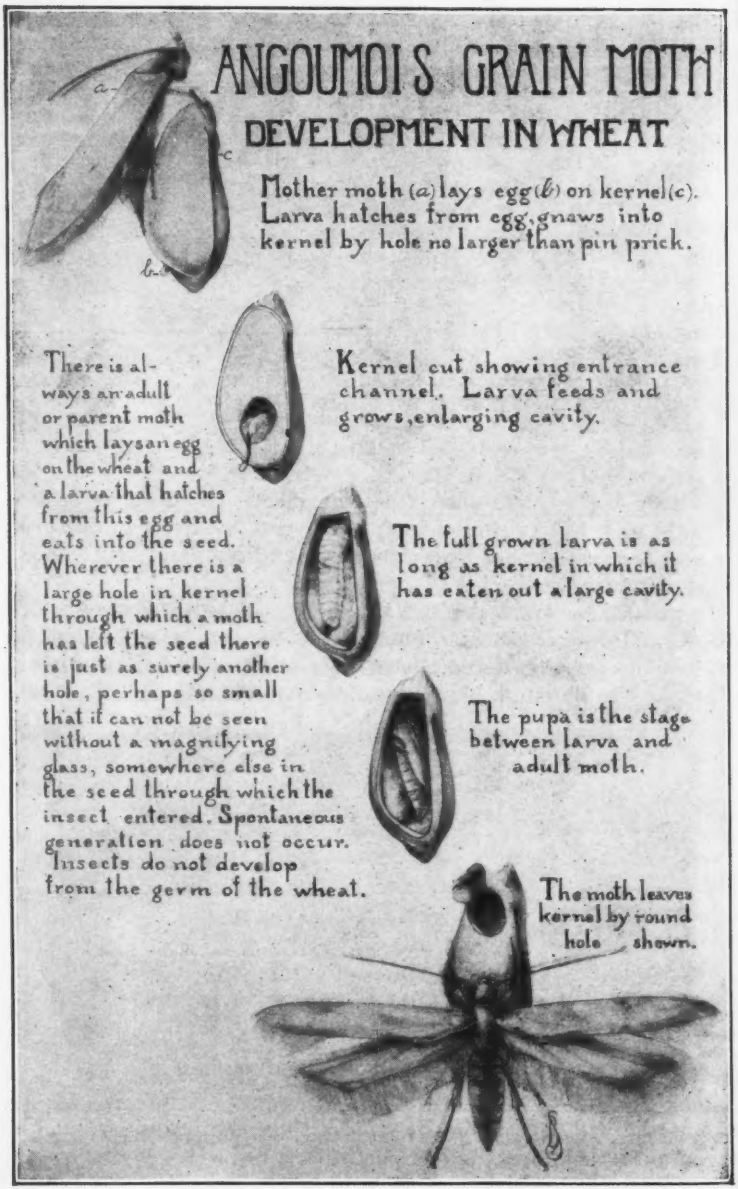
ANGOUMOIS GRAIN MOTH
DEVELOPMENT IN WHEAT
Mother moth (a) lays egg (b) on kernel (c). Larva hatches from egg, gnaws into kernel by hole no larger than pin prick.
There is always an adult or parent moth which lays an egg on the wheat and a larva that hatches from this egg and eats into the seed. Wherever there is a large hole in kernel through which a moth has left the seed there is just as surely another hole, perhaps so small that it can not be seen without a magnifying glass, somewhere else in the seed through which the insect entered. Spontaneous generation does not occur. Insects do not develop from the germ of the wheat.
Kernel cut showing entrance channel. Larva feeds and grows, enlarging cavity.
The full grown larva is as long as kernel in which it has eaten out a large cavity.
The pupa is the stage between larva and adult moth.
The moth leaves kernel by round hole shown.

FIG. 15.—Life cycle of Angoumois grain moth on wheat. (Back.)

Each female moth may lay as many as 150 eggs, which are white when first laid but soon change to a reddish color. The eggs are laid on or near the grain. Upon hatching, the minute white larva or caterpillar bores into a kernel of grain and begins feeding on the contents. When full grown it eats out a channel to the outside of the seed but leaves a thin layer of the seed coat intact. It then changes to a reddish brown pupa, and later the adult or moth emerges, pushing aside the thin section of seed coat that covers the exit from the channel. The development from egg to adult may be completed in five weeks. Figures 15 and 16 show the successive stages in the development of

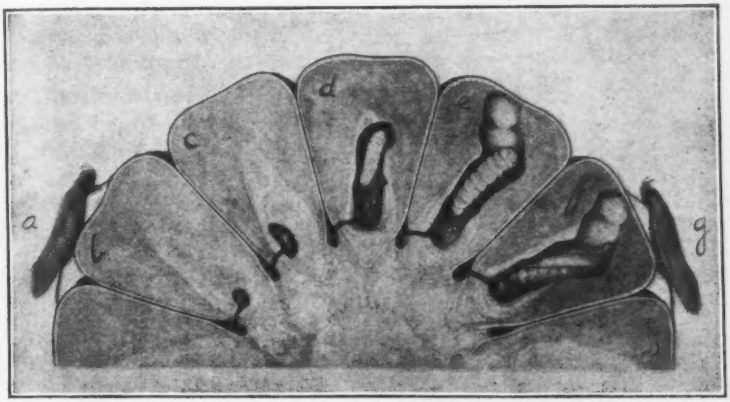

FIG. 16.—Cross section of ear of corn showing development of Angoumois grain moth in corn. The newly hatched larva crawls down to the germ end of the corn and begins feeding upon the soft germ. As it grows older and stronger it eats out into the firmer portion of the kernel and finally, in most instances, eats to the outer end. (Back.)

this insect in a kernel of wheat and of corn from the time the egg is laid until the adult appears. In figure 17 is shown an ear of corn with the external evidence of heavy attack, and in figure 18 are shown wheat kernels with the emergence holes of the moth. For a further discussion of this pest see Farmers' Bulletin 1156, "The Angoumois Grain Moth."

WOLF MOTH.[9]

The wolf moth is a small moth about the size of the Angoumois grain moth, creamy white and thickly mottled with brown. The mottled appearance distinguishes it from the Angoumois grain moth. It infests all kinds of grain, both in the field and in storage. The larva feeds on the grain and webs the kernels together.

[9] *Tinea granella* L.

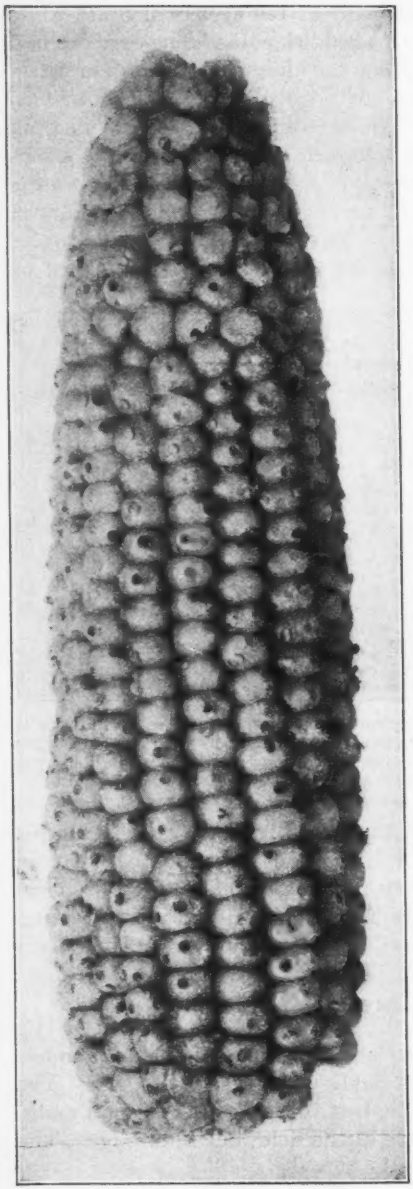

FIG. 17.—Ear of popcorn showing heavy infestation by the Angoumois grain moth. Note that certain of the kernels have three emergence holes, and that many have served as food for two moths. The development of a single insect in a kernel causes a loss of from 13 to 24 per cent in weight.

The wolf moth is distributed throughout the Northern States but is not very abundant and can not be compared with the Angoumois grain moth for destructiveness.

PINK CORNWORM.[10]

The pink cornworm is the larva or caterpillar of a small moth (fig. 19). It is about five-sixteenths of an inch long when full grown; pink in color, with head and thoracic shield pale brown. Figure 20 gives a good idea of its appearance. The moth which develops from this worm or larva is smaller than the Angoumois grain moth, with a wing expanse of slightly less than half an inch. The forewings are banded and mottled with yellow, reddish brown, and black, as shown by figure 19. The pale grayish hindwings are very slender and are edged with long fringes. The pupa is shown in figure 21.

This insect is common in the South, where it causes considerable injury to

[10] *Pyroderces rileyi* Wals.

corn, both in the field and in storage. Infestation begins in the field and is continued after the corn is placed in storage. The very characteristic injury is shown in figures 22 and 23. The large amount of frass that is loosely webbed together and fills the interstices between the kernels or is crowded into the cavities of kernels that have been eaten out is a reliable indication of the presence of this pest. The pearly white eggs are laid singly or occasionally in twos or threes. The pinkish larvæ feed on the seed, husk, and cob with equal relish. Though capable of serious injury to corn, in particular as it comes

FIG. 18.—Kernels of wheat showing the small round emergence holes that prove that the Angoumois grain moth has developed in the seed, thus reducing the weight somewhat over 50 per cent. (Back.)

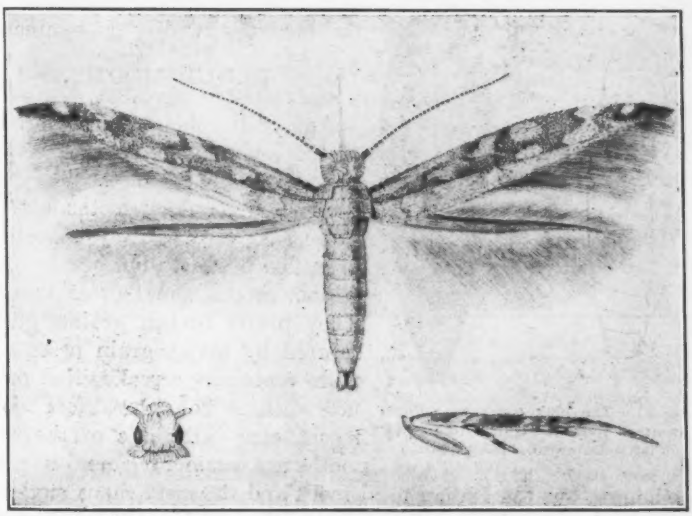

FIG. 19.—The pink cornworm: Moth, much enlarged; head and leg more enlarged. The moth has a wing spread of a little less than half an inch. (Chittenden.)

to maturity in the field, and while in the cribs on Southern farms, the pink cornworm is seldom a serious pest of commercial shipments.

RICE MOTH.[11]

The rice moth has a wing expanse of about half an inch and is of a pale grayish brown or tawny color. Its characteristic appearance is shown in figure 24. The larva (fig. 25) resembles somewhat that of the Indian meal moth, being when full grown about half an inch

FIG. 20.—The pink cornworm: Full-grown larva, side view, greatly enlarged. When full grown the larva is pink and about five-sixteenths of an inch long. (Chittenden.)

long and varying in color from white to a dirty, slightly bluish gray with occasional tints of green. Damage by the pest, as in the case of all moth pests, is done by the larvæ, which feed upon rice, cocoa, chocolate, ships biscuits, etc. The larvæ produce a dense webbing as they become well grown. When feeding upon grains they spin dense silken tubes, webbing the grain kernels into the walls of the tubes. The pupa is shown in figure 26. The rice moth is seldom found in this country and has not become very widely disseminated.

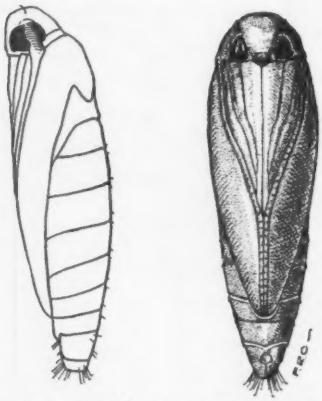

FIG. 21.—The pink cornworm: Pupa, ventral view at right, lateral view at left. Enlarged. (Chittenden.)

FLOUR MOTHS.

Among the flour moths are some of the commonest and most serious pests of grain products. They are designated as flour moths not because they feed entirely upon flour or milled products, but because they seldom attack sound grain kernels. They prefer broken grains, grains injured by major grain pests, and more especially cereal milled products such as flour, breakfast foods, meals, etc. All three of the flour moths are commonly found in grain warehouses, but the Indian meal moth and the meal snout moth are probably the most frequently reported. These two moths may, under specially favorable conditions, become established in whole grain and other seeds and cause injury especially by eating out the germ.

[11] *Corcyra cephalonica* Staint.

INDIAN MEAL MOTH.[12]

The Indian meal moth is a rather handsome moth with a wing expanse of nearly three-fourths of an inch. It is easily distinguished from other grain pests by the peculiar marking of its forewings. These are reddish brown with a coppery luster on the outer two-thirds, but whitish-gray on the inner or body end. Moths and larvæ are shown in figure 27. The female moths lay from 300 to 400 eggs,

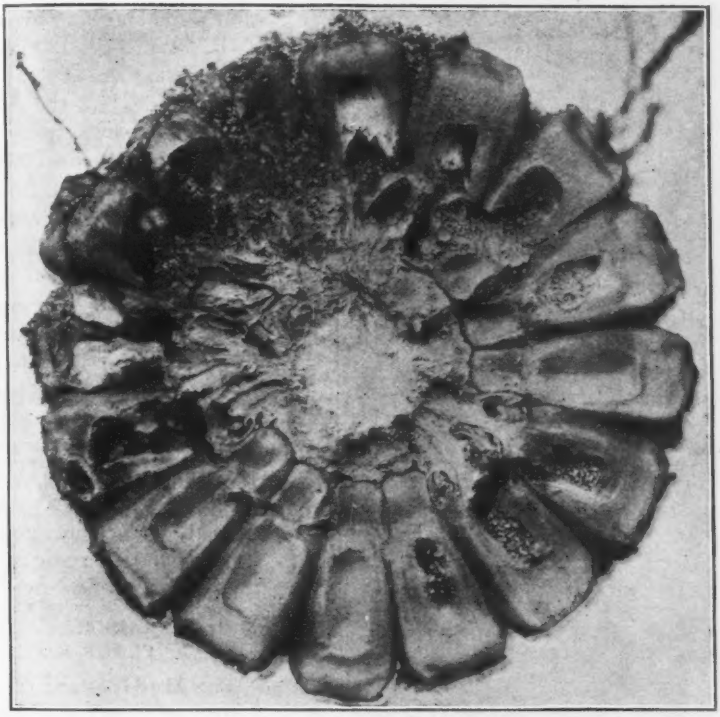

FIG. 22.—Ear of corn cut to show characteristic feeding and destruction by pink corn-worm larvæ. Note that the larvæ eat from one kernel to another, often severing the kernels from the cob. The larvæ sometimes eat into the cob and there transform to the pupa stage. The pupæ are about one-third as long as the kernels shown.

singly or in groups, on food material. The eggs hatch within a few days into small whitish larvæ or caterpillars. These larvæ feed upon grains, grain products, dried fruits, nuts, and a rather wide variety of foodstuffs. When full grown, the larvæ are about half an inch long, dirty white in color, varying sometimes to greenish and pinkish hues. A full-grown larva is shown in figure 28, clinging to a kernel

[12] *Plodia interpunctella* Hbn.

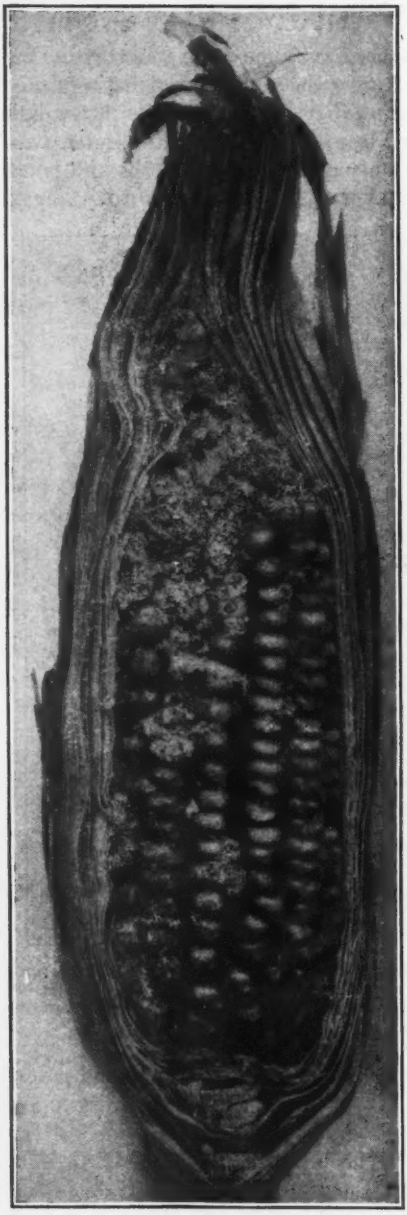

FIG. 23.—Ear of corn with portion of shuck removed to show surface feeding by larvæ of the pink cornworm. Often many kernels drop from the ear when the shucks are removed because of the feeding of the pink cornworm larvæ.

of wheat. This larva spins a silken cocoon and transforms to a light-brown pupa from which the parent moth later emerges. The Indian meal moth may pass through its egg, larva, and pupa stages in about four weeks—during warm weather.

The larva of the Indian meal moth spins a web as it becomes full-grown, and leaves behind a silken thread wherever it crawls. When sacks of cracked corn, meal, or corn in the ear that has been previously injured by other pests become heavily infested, this webbing often is sufficiently abundant to attract attention. The loosely clinging web shown on the ear of corn in figure 29 is characteristic of this pest.

MEDITERRANEAN FLOUR MOTH.[12]

The Mediterranean flour moth has a wing spread of slightly less than one inch. Its hind-wings are a dirty white, but its forewings, which alone show when the moth is not flying, are a pale leaden gray with transverse wavy black markings. (See fig. 30.)

[12] *Ephestia kuehniella* Zell.

The Mediterranean flour moth is a native of Europe. Its first discovery in the United States was in California in 1892. Since then it has spread to practically all the States of the Union and is recognized as the most serious pest of flour mills, owing to the silken threads

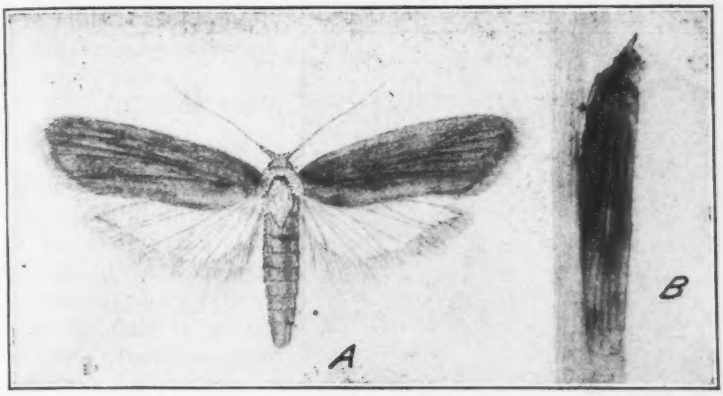

FIG. 24.—The rice moth: *a*, Mature moth, dorsal view, with wings spread; *b*, side view of same moth with wings folded about body. The moth is of a grayish brown or tawny color, with a wing spread of about half an inch. Much enlarged. (Chittenden.)

which the larvæ spin wherever they crawl. These webs mat the flour or meal together and eventually clog machinery so that mills have to shut down for a thorough cleaning and treatment. Although preferring flour and meal, the Mediterranean flour moth attacks grain, bran, and cereal products and is commonly found in storehouses and granaries.

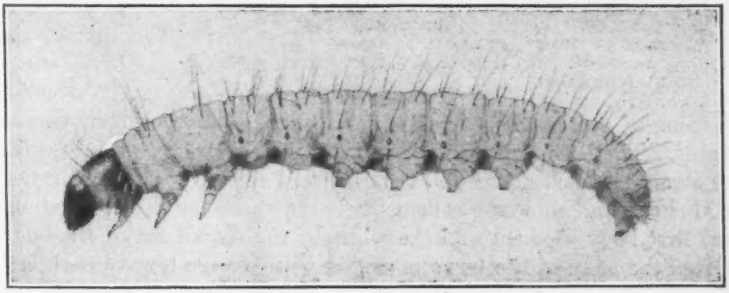

FIG. 25.—Full-grown larva of the rice moth. The full-grown larva is about one-half inch long, and is of a whitish or bluish gray color. Much enlarged. (Chittenden.)

The female moth lays small white eggs in accumulations of flour, meal, or waste grain. From the eggs the small larvæ hatch in a few days. When full grown, these are about half an inch long and are of a whitish or pinkish color with a few small black spots on the body.

The full-grown larva spins a silken cocoon in which the insect transforms to a reddish-brown pupa. Later the parent moth emerges from the pupa. During warm weather, the Mediterranean flour moth requires about nine weeks to pass through its egg, larva, and pupa stages. A more complete discussion of this pest will be found in Bulletin 872 of the United States Department of Agriculture, "Insect Control in Flour Mills."

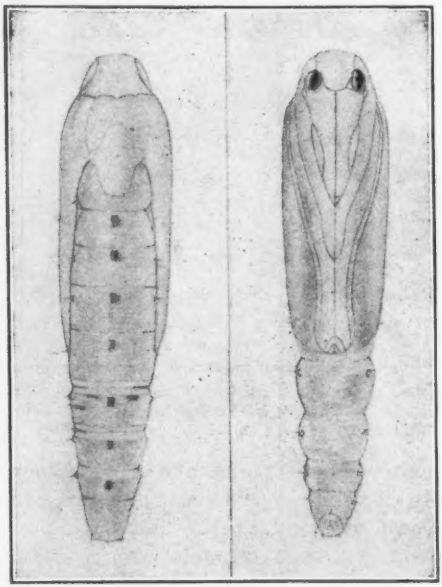

FIG. 26.—Pupa of the rice moth: At left, dorsal view; at right, ventral view. The pupa is found in a dense tough cocoon into the walls of which have been spun particles of the food. The cocoons of the Indian meal moth, on the other hand, are very loosely constructed. Much enlarged. (Chittenden.)

MEAL SNOUT MOTH.[14]

The meal snout moth is brownish in color, somewhat larger than the Indian meal moth, though varying in size, usually having a wing spread of about one inch. Its forewings are marked in a characteristic pattern indicated in figures 31 and 32; they are light brown with dark brown patches at base and tip and each with two wavy transverse white lines. The meal snout moth is widely distributed and a general feeder in the larva stage upon cereals of all kinds both ground and in the berry. It sometimes attracts much attention because of its capacity to web up and bind together seeds of various kinds. The larvæ are whitish and attain a length when full grown of about one inch. The two larger larvæ of figure 31 indicate the normal shape and show the contrast between the black of the head and the first body segment and the white of the remainder of the body. Often the body of the larva is tinged with orange toward each end. The larvæ spin peculiar tubes of silk and particles of the food material. They rest in these tubes, which are very tough, and feed from the openings at the ends. When full grown the larvæ leave the tubes, spin silken cocoons, often covered with food particles, and transform to the pupæ from which later emerge the adult moths.

[14] *Pyralis farinalis* L.

The meal snout moth may require only eight weeks to pass through the egg, larva, and pupa stages.

FIG. 27.—The Indian meal moth: Tip of ear of corn showing, *a*, three moths with their characteristic light and dark markings, and *b*, two well-grown larvæ. The adult moth is distinguished from all other grain-infesting moths by having the outer two-thirds of its wings brownish and the inner third whitish gray. It has a wing spread of about three-fourths of an inch.

The meal snout moth is primarily a pest of seeds that are held for some time in cool and damp localities. Outbreaks that have come to the attention of the authors have always been centered in

grain that was harvested during rainy weather or so stored that the moisture content was unusually high. Attempts to rear the moth in dry, warm laboratories have failed. The larvæ cut through burlap sacking and can damage sacks greatly when heavy infestations develop in sacked material. Figure 33 shows the characteristic webbing together of infested seeds—in this instance navy beans—and figure 32 shows the tendency for larvæ to spin their whitish silken cocoons on the outside of grain sacks where the sacks touch each other.

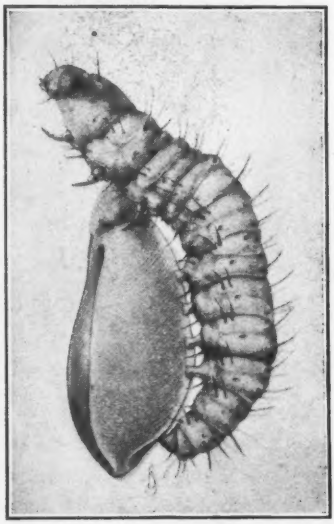

FIG. 28.—Well-grown larva of the Indian meal moth, crawling on kernel of wheat. These worms are white or greenish in color and frequently eat out the germ end of wheat. They attain a length of about half an inch.

MEALWORMS.

There are two species of mealworms in the United States. The adults are the largest of the beetles found in grain and their larvæ are conspicuous, for they attain a length of about one inch and are as large around as an earthworm.

YELLOW MEALWORM.[15]

The adult of the yellow mealworm is a polished dark-brown or black beetle, somewhat more than half an inch long, with its thorax finely punctured and with its wing covers longitudinally striated or grooved. (See fig. 34, at right.) The females lay bean-shaped white eggs covered with a sticky secretion that causes the flour, meal, or grain waste in which they are placed to adhere to them. The eggs hatch in about two weeks into slender white larvæ, which soon turn yellow and assume the form shown in figure 34. When full grown, the larvæ are about an inch long and yellowish, shading to yellowish-brown toward each end and at the articulation of each segment. The pupa into which the larva transforms before becoming an adult beetle is shown in figure 34.

The yellow mealworm is widespread over the world and is frequently found in stored grains. It belongs to a family of beetles[16] known as the darkling beetles because of their preference for dark places. The adults fly only at night. During daylight they conceal themselves, with the larvæ, beneath sacks of grain, under grain boxes,

[15] *Tenebrio molitor* L. [16] Tenebrionidae.

FIG. 29.—Ear of corn showing the loose webbing characteristic of the Indian meal moth larvæ. This moth rarely attacks sound grain, but, as is here shown, frequently attacks grains already injured by other grain pests. Such webbing as is here shown develops only when corn or other grains are left unmoved for some time.

or beneath grain and other food. There is but one generation each year. The adults begin to appear in the latitude of Washington during May and by June have laid most of their eggs and have died. Farther north the adults appear during June. The larvæ become full grown in about three months, but instead of transforming then to the adult stage they continue feeding and molting until cold weather and then hibernate as larvæ. The following spring they transform to the pupa stage, in which the insect passes about two weeks. Because the yellow mealworm has but one generation each year, and is entirely an external feeder upon grains, it need not be feared as a serious pest. Screening and fanning

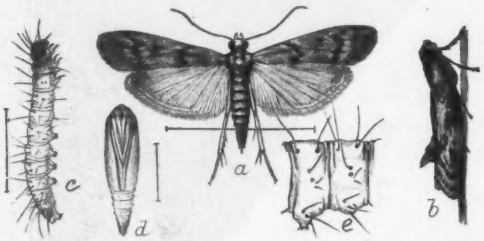

FIG. 30.—The Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa (enlarged); *e*, abdominal joint of larva (more enlarged). The adult moth, with a wing expanse of a trifle less than one inch, is leaden gray in color, marked with transverse wavy black markings. The full-grown larva is whitish or pinkish in color, with small black spots, and is about one-half an inch long. (Chittenden.)

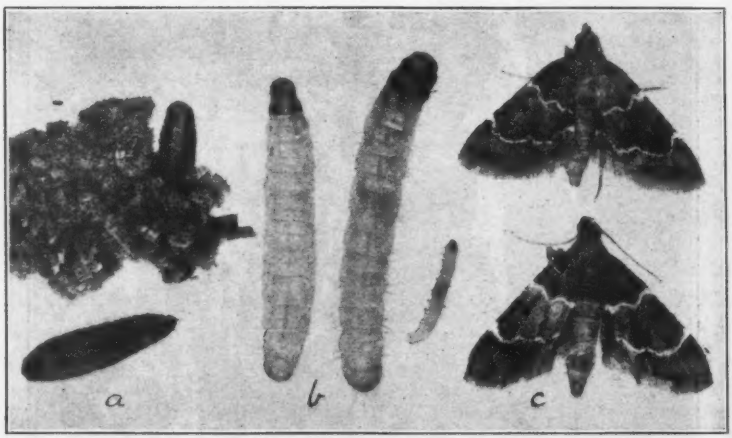

FIG. 31.—The meal snout moth: *a*, Pupa and, above, webbed mass of grain showing portion of pupa protruding; *b*, two well-grown larvæ with a smaller larva at right; *c*, two adult moths. Magnified about one and one-half times. The markings on the forewings easily distinguish this insect from other grain pests.

will remove it easily from grain shipments. The well-grown larvæ, however, can do serious injury to whole grains under certain conditions when grain is held for long periods without being moved.

FIG. 32.—Inside of a grain sack that was filled with infested vetch seed. Note vetch seeds sticking to side of bag as a result of the webs of the larvæ of the meal snout moth, the numerous whitish cocoons with dark pupæ within, and, in the center, one adult moth. Natural size.

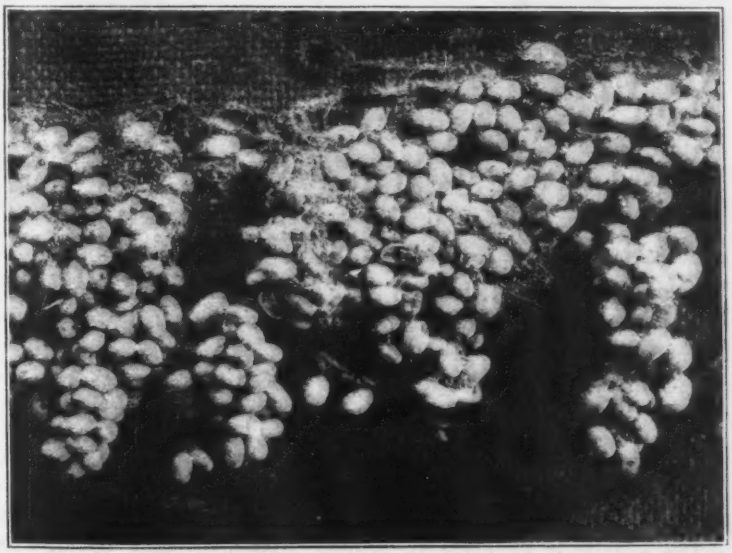

FIG. 33.—Navy beans webbed together by larvæ of the meal snout moth, and adhering to sack. The larvæ often cut sacks so seeds fall out and lodge where sacks touch each other. In these places the seeds are usually more heavily infested.

DARK MEALWORM.[17]

The dark mealworm, as may be seen by the larva, pupa, and adult shown in figure 35, is very similar in form, size, and color to the yellow mealworm, to which it is closely related. The adult beetle differs, however, in being dull pitchy black, in contrast to the shiny or polished dark brown or black of the yellow mealworm. Its larva so closely resembles the larva of the yellow mealworm that it can be distinguished most easily by its much darker color. The two

FIG. 34.—The yellow mealworm. Four well-grown larvæ, two pupæ, and the black adult beetle, with five kernels of wheat to indicate relative size. The larvæ when full grown are about one inch long and yellowish. The adult beetles are shiny black and slightly more than half an inch long.

species of mealworm are often found associated, and what has been said of the stages of the yellow mealworm applies equally well to the dark mealworm.

GRAIN AND FLOUR BEETLES.

CADELLE.[18]

The cadelle is an elongate, oblong, flattened, black or blackish beetle about one-third of an inch long. It resembles the mealworms

[17] *Tenebrio obscurus* Fab.

[18] *Tenebroides mauritanicus* L.

in appearance, but is much smaller and the thorax and abdomen are loosely joined. (See fig. 36.)

The larva of the cadelle is one of the largest of the grain-infesting insects and is easily recognized. It is about three-quarters of an inch long, fleshy, with the abdomen terminating in two dark horny points. The larva is a dirty or chalk white, with head, thoracic shield, and the two horny points at end of body black, as shown in figure 37.

This insect is widespread over the world and is frequently found in mills, granaries, and storehouses, where it infests flour, meal, grain, etc. Both larva and adult feed on grain and have the destructive habit of going from kernel to kernel and devouring the embryo.

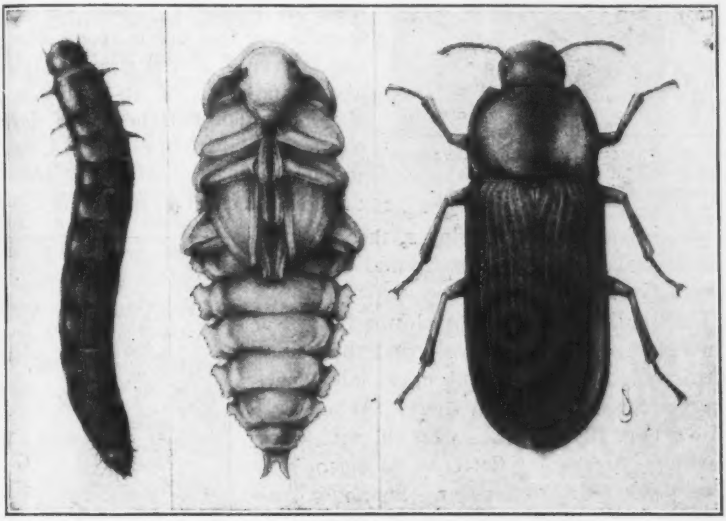

FIG. 35.—The dark mealworm: *a*, Full-grown larva; *b*, pupa; *c*, adult beetle. Distinguished from the yellow mealworm by the dark brown color of the larva and the dull, not shiny appearance of the adult beetle. For true relative size of the larva, pupa, and adult compare with figure 34.

The cadelle often becomes well established in ear corn (fig. 38) that has first been injured by the Angoumois grain moth or by the weevils. The long slits in corn kernels shown in figure 38 are characteristic of cadelle infestation. Were it not for the fact that there is not more than one generation of this insect each year the cadelle would be one of the most serious enemies of stored grain. As it is it is probably the longest lived of the insects that attack stored grain, and frequently causes severe losses.

The white eggs are laid in clusters in the food material selected and hatch in about 10 days. When the larvæ become fully grown they seek some secluded place in which to transform to the pupa (fig. 39), frequently boring into the timbers of the bin or other re-

FIG. 36.—The cadelle: Adult beetle. The cadelle is a flattened, black beetle about one-third of an inch long.

ceptacle that holds the infested material. Both larvæ and beetles feed to some extent on other grain-infesting insects, hence are partly predacious.

SAW-TOOTHED GRAIN BEETLE.[19]

The saw-toothed grain beetle gains its name from the peculiar structure of the thorax, which bears six sawtoothlike projections on each side (fig. 40). This character is a ready means of distinguishing this beetle from others that infest stored grain. It is about one-tenth of an inch long, slender, much flattened, and dark chocolate brown in color. A cosmopolitan beetle, extremely abundant at times, it is nearly omnivorous, infesting grains, flours, meals, dried fruits, seeds, etc. Both beetle and larva are very active.

The small slender eggs hatch in a few days. The emerging larvæ do not spend their lives within a single grain but crawl about actively, feeding here and there. When full grown (fig. 40), they are whitish, with dark markings, somewhat flattened in form, and have three pairs of legs and an abdominal proleg. When ready to pupate they construct delicate cocoon-like coverings by joining together small grains or fragments of foodstuffs with a sticky secretion and within this the pupa (fig. 40) and later the adult form are assumed. Development from egg to adult may take place in 24 days in summer.

FIG. 37.—The cadelle: Larva. Commonly found crawling among grain kernels. It may appear glistening white or dull and powdered according to the material in which it is crawling. When full grown it is about three-fourths of an inch long.

SQUARE-NECKED GRAIN BEETLE.[20]

The square-necked grain beetle is closely related to the saw-toothed grain beetle, which it greatly resembles in form, size, and color. It is a flattened, oblong, polished, reddish brown beetle about one-tenth of an inch long. It differs from the saw-toothed grain beetle

[19] *Oryzaephilus surinamensis* L. [20] *Silvanus gemellatus* Duv.

by having the thorax almost square in shape and lacking the sawtoothlike projections. (Fig. 41.)

This beetle is chiefly abundant in the South, where it is found in great numbers outdoors infesting the seed pods of a great variety of plants. It is one of the most common beetles in stored corn in the South and in the cornfields is always to be found on damaged or exposed ears. The immature stages closely resemble those of the preceding species both in form and in habit. The larvæ have the bad habit of devouring the germ of the seed in which they breed. They can develop from egg to adult in about three weeks.

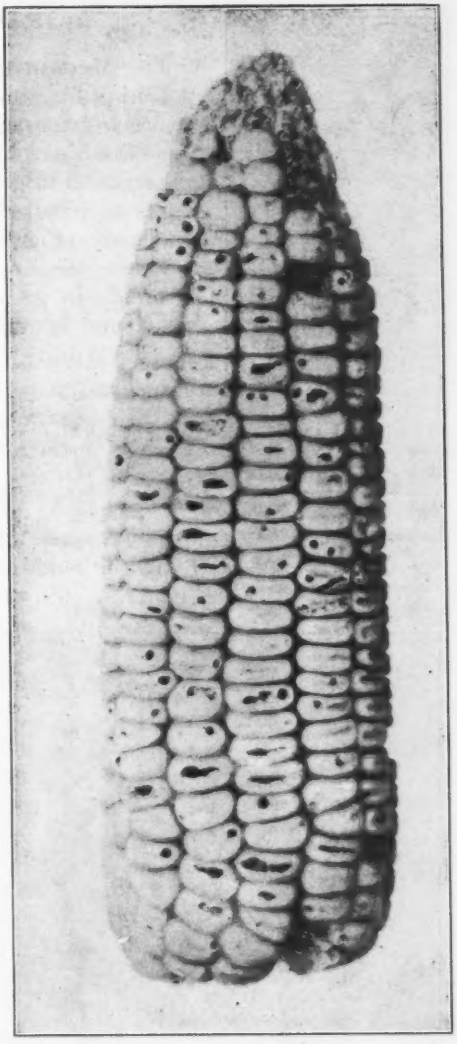

FIG. 38.—Ear of corn infested by the Angoumois grain moth (round holes in kernels) and the cadelle. The elongated slits in the kernels are characteristic of cadelle feeding and emergence. Only ear corn stored for several years will develop this evidence of cadelle attack.

FOREIGN GRAIN BEETLE.[21]

The foreign grain beetle is a small reddish brown beetle somewhat similar in appearance to the preceding species, to which it is closely related. It differs from it by being smaller and more robust. (Fig. 42.) Although of world-wide distribution, it is of little consequence as an enemy of stored grains. It is attracted to damp and moldy grains and feeds on the molds developing in such grains. It is rarely found in clean grain.

[21] *Cathartus advena* Waltl.

FIG. 39.—The cadelle: Pupa, much enlarged. The pupa is seldom seen as this stage of the cadelle's life cycle is spent in a cell made in an inaccessible place.

MEXICAN GRAIN BEETLE.[22]

The Mexican grain beetle is a highly polished, deep brown beetle about three-sixteenths of an inch long. While resembling somewhat the confused flour beetle in general appearance, it can be readily distinguished by its more polished surface and by its longer antennæ. (Fig. 43.)

This insect is common in Mexico, where it breeds in grain and grain products. It was found in this country in grain exhibits at the World's Columbian Exposition, but is not known to be permanently established in this country as yet. It may be found in grain in the extreme South.

SIAMESE GRAIN BEETLE.[23]

The Siamese grain beetle is an elongate, flattened, reddish-brown beetle slightly less than an eighth of an inch long characterized

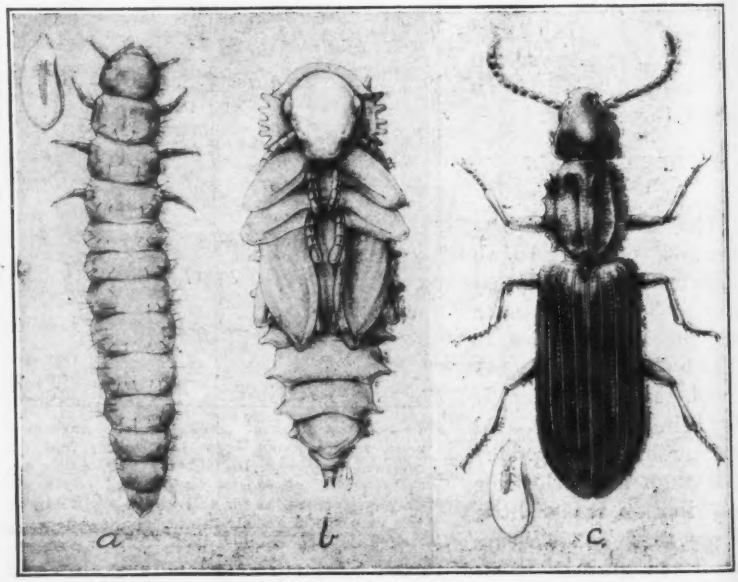

FIG. 40.—The sawtoothed grain beetle: *a*, Well-grown larva, with kernel of wheat to show its relative size; *b*, pupa; *c*, adult beetle with kernel of wheat to show its relative size. The adult beetle, about one-tenth of an inch in length, can be easily recognized by the six toothlike projections on the sides of the thorax.

[22] *Pharaxonotha kirschi* Reitt. [23] *Lophocateres pusillus* Klug.

by the much flattened margins of the thorax and wing covers (fig. 44).

First appearing in exhibits of rice and cereals from Siam, Liberia, and Ceylon at the World's Columbian Exposition, it has since been reported as injurious to stored grain and grain products in South Carolina and Texas. It is likely to be found in seaport towns and in the Southern States, but as yet it is not abundant or widespread.

FIG. 41.—The square-necked grain beetle. (Chittenden.)

FLAT GRAIN BEETLE.[24]

The flat grain beetle is a small, flattened, oblong, reddish-brown beetle about one-sixteenth of an inch long, with elongate antennæ somewhat longer than half the length of its body. (Fig. 45.) It is readily distinguished because it is the smallest beetle commonly found in stored grain in this country. It is cosmopolitan in distribution, is very generally found in stored corn in the South, and is often screened from wheat shipments. Little is known of its habits or of its early stages, though it is thought to be a scavenger or predacious on other insects. The full-grown larvæ form cocoons of a gelatinous substance to which food particles adhere. While it is present sometimes in unbelievable numbers in grain shipments, it appears to do little damage to whole grains. The larvæ have been found destroying the germ in kernels of wheat.

FIG. 42.—The foreign grain beetle. (Chittenden.)

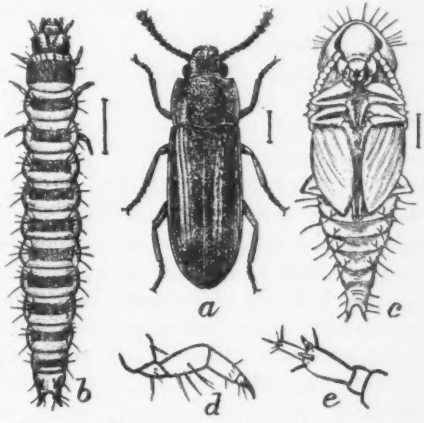

FIG. 43.—The Mexican grain beetle. *a*, Beetle; *b*, larva; *c*, pupa; *d*, leg of larva; *e*, antenna of larva. *a*, *b*, *c*, Much enlarged; *d*, *e*, more enlarged.

[24] *Cryptolestes pusillus* Schön.

CONFUSED FLOUR BEETLE.[25]

The confused flour beetle (fig. 46) is a shiny, reddish-brown beetle about one-sixth of an inch long, flattened and oval in form, with head and upper parts of thorax densely covered with minute punctures and with wing covers ridged lengthwise and sparsely punctured between the ridges. It is generally distributed over the world and is very abundant in all parts of this country. It is known as one of the flour beetles owing to its frequent occurrence in flour. It is a general feeder on starchy foods and is probably the worst insect pest of prepared cereal foods. It is constantly found in granaries, mills, and storehouses, and grain shipments.

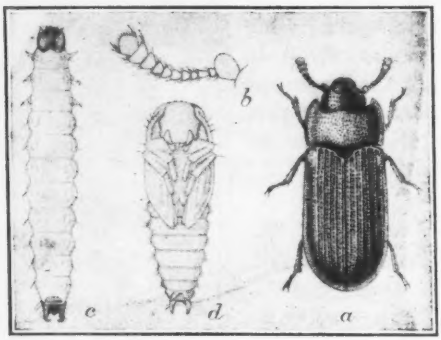

FIG. 44.—The Siamese grain beetle. *a*, Beetle; *b*, antenna of same; *c*, larva; *d*, pupa. *a*, *c*, *d*, About ten times natural size; *b*, greatly enlarged.

The minute white eggs of this beetle are laid in the cracks and crevices of bins, barrels, boxes, or other containers of the foodstuffs attacked by this insect. They are covered with a sticky secretion so that they become covered with flour, meal, etc., and readily adhere to the sides of sacks, boxes, and other containers so that fresh material placed in them is rapidly infested. The eggs hatch into small wormlike larvæ, slender, cylindrical, and wiry in appearance. When fully grown they are about three-sixteenths of an inch long, and in color are white, tinged with yellowish. These larvæ feed on flour or other material such as grain dust and the broken surfaces of grain kernels. When full grown they transform to small naked pupæ. At first white, the pupæ gradually change to yellow and then brown, and shortly afterwards transform to beetles. The period from egg to adult in summer is about four weeks under most favorable weather conditions, though the

FIG. 45.—Adult of the flat grain beetle, showing characteristic long antennæ. Not more than one-sixteenth of an inch long. This beetle is one of the very smallest found in grain shipments.

[25] *Tribolium confusum* Duv.

life cycle is greatly prolonged by cold weather, as is true of all grain pests.

RUST-RED FLOUR BEETLE.[26]

The rust-red flour beetle is almost identical in appearance with the preceding species, to which it is closely related. It can be distinguished from the confused flour beetle only with the aid of a magnifying glass. The segments of the antennæ of the confused flour beetle increase in size gradually from the base to the tip, while in the rust-red flour beetle the last few segments of the antennæ are abruptly much larger than the preceding ones, giving the antennæ the appearance of being suddenly enlarged at the tip. In addition, the margins of the head of the confused flour beetle are expanded and notched at the eyes, while the margins of the head of this species are nearly continuous at the eyes. The differences between the two species are clearly shown in figure 46, *e* and *f*.

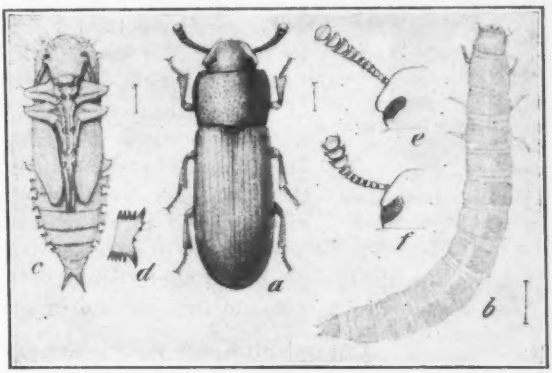

FIG. 46.—The confused flour beetle, the commonest insect recovered from grain shipments. It is about one-sixth of an inch long. *a*, Beetle; *b*, larva; *c*, pupa; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle, showing antenna; *f*, same of the rust-red flour beetle. (Chittenden.)

This insect is similar to the confused flour beetle in feeding and breeding habits, and it is impossible to distinguish between the early stages of the two insects. Although cosmopolitan in distribution, it is found more commonly in the South, where it causes very serious damage to grain products. In addition to the actual damage caused by its feeding activities, serious losses are caused by the nauseous smell and taste that it imparts to the material it infests. Like the confused flour beetle, the rust-red flour beetle is primarily a pest of milled products, and while present in grain shipments it confines its attack in these to grain dust and the surface of broken grains, hence is not a primary pest of commercial shipments.

LONG-HEADED FLOUR BEETLE.[27]

The long-headed flour beetle is a slender, flattened beetle, slightly less than an eighth of an inch long, somewhat similar in form to the

[26] *Tribolium ferrugineum* Fab.

[27] *Latheticus oryzae* Waterh. A closely related species, *Latheticus prosopsis* Chittn., is shown in figure 48.

confused flour beetle but pale yellow and further differentiated by the peculiarly shaped antennæ shown in figure 47 and by the minute canthus behind each eye. It has been reported from most parts of the world infesting wheat, rice, corn, barley, rye, flour, etc. It was first recognized in this country about 13 years ago from specimens taken in Texas. It is not known to be very widely distributed in the United States but is likely to be found in mills and granaries in the South.

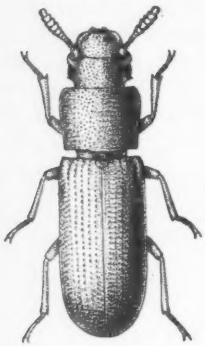

FIG. 47.—Long-headed flour beetle. (Chittenden.)

SLENDER-HORNED FLOUR BEETLE.[28]

The slender-horned flour beetle owes its name to the peculiar structure of the mandibles or jaws of the male, which are armed with a pair of slender incurved horns as shown in figure 49. The beetle is about one-eighth of an inch long, flattened and brownish, closely resembling the other flour beetles in appearance but easily distinguished by the peculiar structure of the jaws. It is distributed over the world and of frequent occurrence in the Southern States. It prefers to feed in flour and meal, but is found in a variety of grains.

BROAD-HORNED FLOUR BEETLE.[29]

The broad-horned flour beetle is closely related to the preceding species and is of similar form and appearance. It may be distinguished from it by the shape of the horns with which the mandibles or jaws of the males are armed. In this species (fig. 50) the horns are broad and stout in contrast to the slender incurved horns of the preceding species. Its habits are similar to those of the slender-horned flour beetle, and it is often found in seaport towns in shipments of grain and grain products.

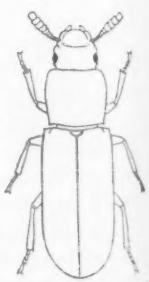

FIG. 48.—*Latheticus prosopis.* (Chittenden.)

SMALL-EYED FLOUR BEETLE.[30]

The small-eyed flour beetle (fig. 51) is the smallest of the so-called flour beetles that infest grain and grain products in this country. It is a tiny, flattened, shiny, reddish-brown beetle, somewhat oblong in form and measuring about one-twelfth of an inch in length. It occurs throughout the world and is widely distributed in this country. It prefers ground products in which to breed, but is not infrequently found in stored grains.

[28] *Gnathocerus maxillosus* Fab. [29] *Gnathocerus cornutus* Fab. [30] *Palorus ratzeburgi* Wism.

A closely related species[31] more common in Europe but occasionally found in this country is very similar in appearance and habits to the small-eyed flour beetle.

TOBACCO BEETLE.[32]

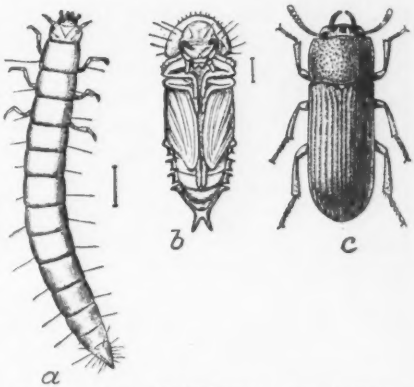

FIG. 49.—The slender-horned flour beetle: *a*, Larva; *b*, pupa; *c*, beetle. (Chittenden.)

The tobacco beetle is a small, robust, oval, reddish-yellow or brownish red beetle, with head bent down nearly at right angles to the body, giving the beetle a humped appearance when viewed from the side as shown in figure 52. It varies in size, but is usually about one-tenth of an inch long. It is found in all temperate, subtropical, and tropical regions and infests tobacco and many other stored products. It breeds in a variety of seeds and may occasionally be found attacking grains left long in storage in original sacks.

DRUG-STORE BEETLE.[33]

The drug-store beetle is very similar in appearance to the tobacco beetle, to which it is closely allied, but differs from it by being more elongate in proportion and in having the wing covers distinctly striated. It is about one-tenth of an inch long. It is cylindrical and uniform light brown; its body is covered with a fine silky pubescence. (See fig. 54.) The larva or grub is very much less hairy than that of the cigarette or tobacco beetle, as a comparison of figures 53 and 55 will show. It is known as the drug-store beetle from its habits of feeding on almost all drugs found in pharmacies. It is a very general feeder, attacking a great variety of stored foods, seeds, and other materials, and has been said to "eat anything except cast iron." It is frequently found in storehouses and granaries in all parts of the world.

FIG. 50.—The broad-horned flour beetle. (Chittenden.)

The eggs of this beetle are laid in almost any dry organic substance. The small white grubs emerging from the eggs tunnel through these substances and when full grown pupate in small cocoons. The entire life cycle may be passed in less than two months.

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[31] *P. depressus* Fab. [32] *Lasioderma serricorne* Fab. [33] *Sitodrepa panicea* L.

FIG. 51.—The small-eyed flour beetle. (Chittenden.)

BLACK CARPET BEETLE.[34]

The black carpet beetle is a small oval beetle between two-sixteenths and three-sixteenths of an inch long. The head and thorax are black, but the wing covers may be either black or dark reddish brown, and clothed with short hairs. Its legs and antennæ are dark yellowish in color. The larva is very characteristic and can be readily recognized. It is reddish or golden brown, clothed with short scale-like appressed hairs and provided with a tuft of long hairs at the end of the body, as shown in figure 56.

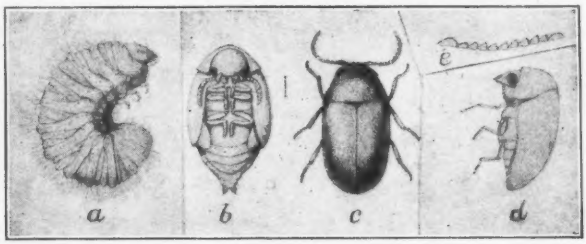

FIG. 52.—The tobacco beetle never attacks grain unless it has been stored for long periods. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden.)

As the name indicates, this insect injures carpets, but in addition it is known to breed in grains and cereals, both whole and ground. The larval stages develop very slowly, and there is but one generation each year. The adults appear in greatest numbers during the spring and early summer. It occurs in Europe and Asia and has been reported from all parts of this country. It is of very common occurrence in houses.

FIG. 53.—The tobacco beetle: Head and leg of larva. (Chittenden.)

LARGER CABINET BEETLE.[35]

The larger cabinet beetle is a small, oval beetle about one-eighth of an inch long, its ground color black mottled with reddish brown, covered with gray and light brown scale-like hairs forming a distinct pattern on the wing covers. The larva somewhat resem-

[34] *Attagenus piceus* Oliv. [35] *Trogoderma tarsale* Melsh.

bles that of the black carpet beetle in appearance. It is about one-eighth of an inch long, reddish brown above and whitish beneath, with body covered with short yellowish brown hairs and with a tuft of short hairs at the tail end. (See fig. 57.) It is well known for its habit of breeding in dead insects and animal substances and is not infrequently found living in grain, flaxseed, castor beans, pumpkin seed, etc. It often becomes a nuisance in laboratories by attacking sample lots of corn, wheat, etc.

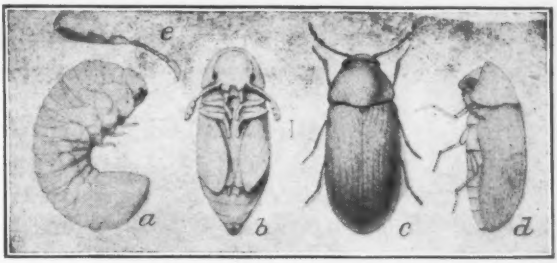

FIG. 54.—The drug-store beetle never attacks grain unless it is stored for long periods unmolested. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden.)

SMALL CABINET BEETLE.[36]

The small cabinet beetle is somewhat similar in appearance to the larger cabinet beetle but smaller and of different color. It varies in length from one-sixteenth to two-sixteenths of an inch, and is black with yellowish white scales that form a broad band across the back and give the body a mottled appearance. The habits of the adult and early stages of this insect are similar to those of the larger cabinet beetle. It is occasionally found in flour mills and granaries, where it infests grain and grain products.

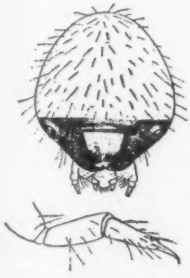

FIG. 55.—The drug-store beetle: Head and leg of larva. (Chittenden.)

MUSEUM BEETLE.[37]

The museum beetle is closely allied to the preceding beetle and resembles it in size and form. Its body is black, covered with yellowish and whitish scales, giving it a spotted appearance. It is a small plump beetle varying in size from one-sixteenth to one-eighth of an inch in length. The larvæ are small active hairy grubs with habits similar to those of the two preceding species. They are occasionally found in grains, both whole and ground, but do not cause noticeable damage.

TWO-BANDED FUNGUS BEETLE.[38]

The two-banded fungus beetle is a handsome little elongate-oval beetle slightly less than an eighth of an inch long. It is red-brown with two broad black bands across the wing covers. Its character-

[36] *Anthrenus verbasci* L. [37] *Anthrenus museorum* L. [38] *Alphitophagus bifasciatus* Say.

istic color pattern is shown in fig. 58. It is distributed over the world and is in general a feeder on fungi and molds, being a scavenger in refuse grain and grain products, decaying vegetable matter, etc. It is frequently found around mills and storehouses where waste material is allowed to accumulate. The larvæ have been bred from moist cornmeal and in spoiled cereals. The insect is often found in the holds of grain ships in wet or damaged grain.

BLACK FUNGUS BEETLE.[39]

The black fungus beetle (fig. 59) resembles the mealworm beetles in form and color but is considerably smaller. It is black or a very dark reddish brown and measures from three-sixteenths to four-sixteenths of an inch in length. The larva (fig. 59, *a*) is yellowish

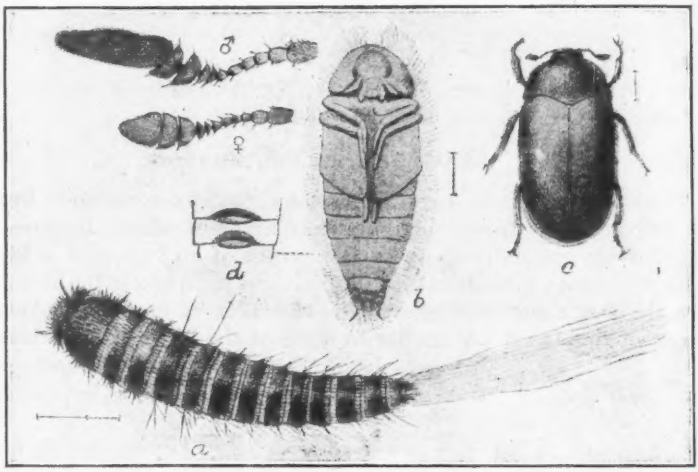

FIG. 56.—The black carpet beetle is chiefly a pest of sample grains, or found in grain dust about elevators or storage bins. *a*, Larva; *b*, pupa; *c*, beetle; *d*, dorsal abdominal segments of pupa; ♂, antenna of male beetle; ♀, antenna of female beetle. (Howard.)

brown and is very similar in form and appearance to young larvæ of the mealworms. This beetle is often found in the same situations as the red-banded fungus beetle. It breeds in damp moldy grain but causes no injury to grain that is sound and dry.

CORN SAP-BEETLE.[40]

The corn sap-beetle may be readily recognized by its peculiar wing covers, which are short and truncate, leaving the tip of the abdomen exposed as shown in figure 60. It is a small dark brown beetle with lighter colored wing covers, oblong-ovoid in shape, and varying in length from one-tenth to one-eighth of an inch. It normally feeds in

[39] *Alphitobius piceus* Oliv. [40] *Carpophilus dimidiatus* Fab.

rotting and decaying fruit and vegetation and in the sap exuding from injured plants. It is quite numerous in cornfields in the South, swarming over the damaged ears and feeding and breeding in the decaying kernels. It is attracted to damp and decaying grain but is seldom found in grain that is clean and dry.[41]

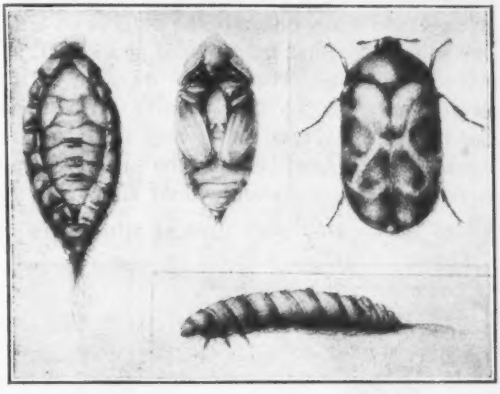

FIG. 57.—The larger cabinet beetle: At left, pupa within larval skin; in center, pupa; at right, beetle; below, well-grown larva.

A closely related beetle[42] that has been introduced from abroad and is becoming more and more abundant is similar in form to the corn sap-beetle, but is slightly larger and is a uniform, shiny, dark brown all over. Its habits are very similar to those of the preceding species.

BOOK-LICE OR PSOCIDS.[43]

Book-lice or psocids are minute, pale, soft-bodied, louse-like insects, about one thirty-second of an inch long, with long, slender antennæ, differing greatly in appearance from other grain-infesting insects. (See fig. 61.) They may be whitish, almost transparent, or quite dark.

FIG. 58.—The two-banded fungus beetle. Adult.

Psocids are of very common occurrence and may be found in nearly any situation. They are almost omnivorous, feeding on any animal or vegetable matter. They are frequently found in grain, but while they have jaws and are capable of feeding upon solid materials, they may be disregarded as pests of grain. They are frequently very abundant in grain and are here recorded because of the curiosity of persons to know what they are. For further information regarding them see Farmers' Bulletin 1104, "Book-Lice or Psocids."

[41] *Carpophilus pallipennis* Say, a purely flower-infesting beetle, has been occasionally reported as infesting stored corn. In these cases large specimens of the corn sap-beetle which closely resemble this species were probably mistaken for it.

[42] *Carpophilus humeralis* Murray.

[43] *Troctes divinatoria* Fab. *et al.*

MITES.[44]

Mites are pale-colored, soft-bodied creatures provided with numerous long hairs, as illustrated in figure 62. They are microscopic in size. As a low estimate the number of mites that may be found on one square inch has been placed at 100,000. They are often found in stored grain and occasionally increase with such rapidity that the grain seems to be fairly alive with them. During heavy infestations their cast skins and dead bodies accumulate in fluffy light brown masses beneath the sacks of grain. If these accumulations are on a warehouse floor they roll up into piles which are blown about with each gust of wind. No other group of pests in

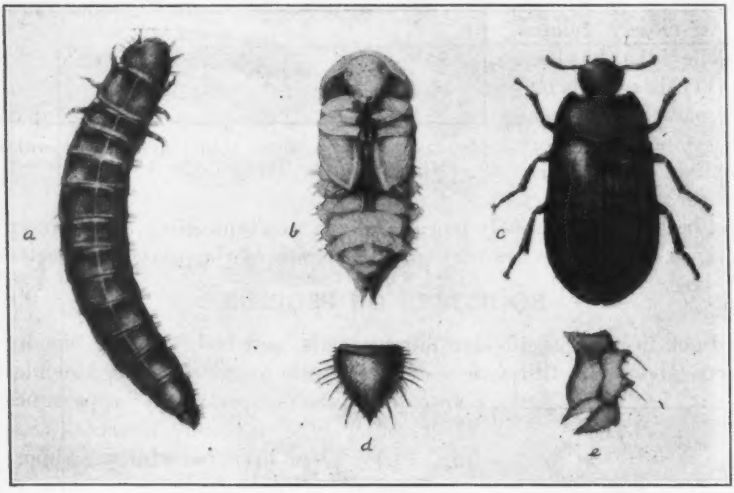

FIG. 59.—The black fungus beetle: *a*, Larva; *b*, pupa; *c*, adult; *d*, caudal segment of larva (Schlödte); *e*, lateral plate of pupa (Schlödte).

grain will produce these masses. When present in large numbers they promote "sweating," impart a disagreeable odor to the grain, and may cause damage by their feeding. Fortunately the mites that attack grain are themselves preyed upon by predacious mites which usually become abundant enough to kill the grain mites in a comparatively short time. If they do not, the screening and fanning of grain will usually reduce mite infestations to a point where no injury takes place.

PARASITES OF GRAIN PESTS.

Grain in bulk is often seen swarming with small black wasplike insects of a size and appearance shown in figure 63. These do

[44] *Tyroglyphus* spp.

not cause injury to grain. On the contrary, they are beneficial, as they are attacking and killing the grain weevils and grain moths. While parasites kill a large number of grain insects, they unfortunately can not be considered of great importance from the standpoint of grain protection, for by the time the grain insects have been controlled by parasites the grain itself has become very badly damaged. For this reason the appearance of a large number of parasites in grain cars or elevators should be disregarded and the grain treated as though parasites were not present.

FIG. 60.—The corn sap-beetle. Adult.

Grain dealers frequently find a small threadlike white worm [45] (fig. 64) about three-quarters of an inch long in grain dust beneath sacks or in the bottoms of bins. This is the larva of a small black fly to be found crawling upon windows of granaries and flour mills. Because of this habit it is called the window-pane fly. Its threadlike larva does no harm to grain but is predacious upon the larvæ of grain pests and clothes moths. It is not abundant enough to be of value in protecting grain.

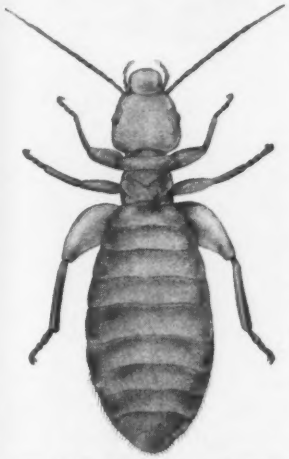

FIG. 61.—Book-louse or psocid.

HOW GRAIN BECOMES INFESTED.

Grain may become infested in a number of ways. It is never possible to settle satisfactorily litigation over responsibility for insect damage to grain without a thorough knowledge of the history of the particular grain shipment involved.

Several of the worst insect pests of grain, notably the Angoumois grain moth and the rice or black weevil, fly to the grain fields from near-by cribs and begin their attack upon the maturing grain. In the case of wheat and similar small grains, the eggs of the insect are laid directly upon the heads of grain. In the case of corn the insects can infest only those kernels that are exposed because of poorly de-

[45] *Scenopinus fenestralis* L.

veloped or damaged shuck covering. In cornfields, especially in the South, where insect infestation occurring in the field is most severe, there are a sufficiently large number of exposed kernels to bring about slight, though widespread, infestation.

It is probably true that in well-grown crops of corn the percentage of kernels infested before the crop is ready for harvest is very small, and throughout the Middle and Northern States is a negligible factor. In the Gulf Coast States, especially in upland fields, the infestation often is very severe. In the case of wheat, grown particularly along the Ohio River, in southern New Jersey, in Pennsylvania,

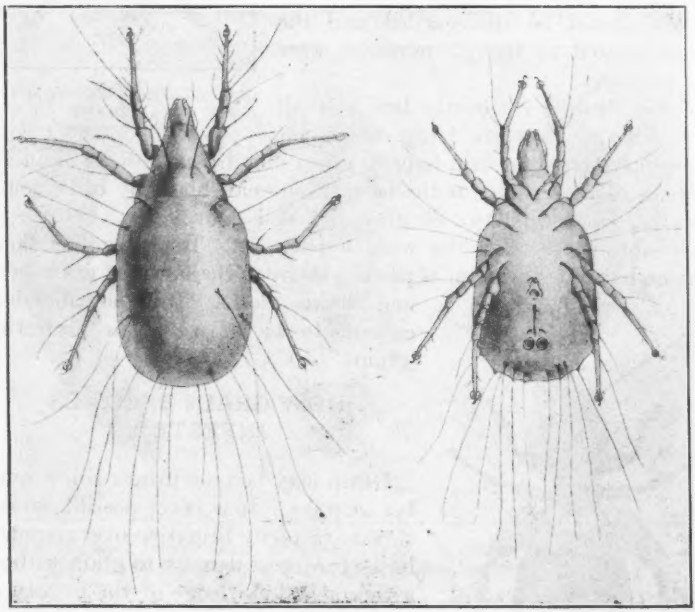

FIG. 62.—Grain mites. (Howard.)

Maryland, Delaware, Virginia, and southward, the field infestation may be much more general than is now believed. Newly thrashed wheat from Maryland arriving in September on the Baltimore market showed infestation ranging up to 6 per cent. While these infestations occurring in the grain before it is harvested are usually unavoidable, they are of great importance as "leaven" which in storage may result in a general infestation of an entire crop, in heating, and in much damage.

After grain has been harvested it is often stored in bins, storehouses, or barns that have held, or still hold, infested grain and which

have not been thoroughly cleaned. Wooden bins and wooden partitions in grain storehouses and in the holds of grain-carrying ships become the nesting places for an incredibly large number of grain pests. Certain of these can and do bore into the softer portions of the partitions and timbers that are used over and over again as dunnage, and the excavations they make serve as hiding places not only for themselves but all other species associated with them. Unless such bins and partitions are thoroughly disinfected by fumigants, these hidden insects can not be killed. The mere spraying of contact insecticides upon the walls will not reach them. If uninfested grain is placed in such bins, it naturally will become infested by the insects coming from the bin walls.

FIG. 63.—Hymenopterous parasite of grain pests. Adult parasite resting upon a kernel of wheat. These tiny gnat-like insects are beneficial but their help usually comes too late to prevent damage to the crop in which they are most abundant.

FIG. 64.—Larva of a kind of fly that preys upon grain beetles and mites. This white threadlike worm is sometimes found in grain dust and attains a length of about three-fourths of an inch; while interesting, it is of no practical value.

Likewise, uninfested grain should not be placed for shipment in sacks previously used for grain storage, for, as shown in figure 32, these old sacks often harbor insects unless they have been treated by heat or fumigation. Certain extensive and costly infestations have been traced directly to the use of secondhand untreated grain sacks.

Grain stored in the open or in poorly constructed cribs or bins may become infested by insects flying in from outside sources.

HOW TO PREVENT PRIMARY INFESTATION.

Infestation of grain in the field can not be entirely prevented, but by proper precautions it can be reduced to a minimum. The first gen-

eration of insects in the maturing grain is usually small, and if the grain is cut as soon as ripe, thrashed as soon as dry, and then placed in storage in clean, deep bins the damage from this source will be very slight. It is when the grain is left in the field long after it is ripe that serious infestation results, for the insects increase in one or two generations to enormous numbers. In the case of corn in the field, only those ears that are damaged or through poor shuck development have kernels exposed are subject to the attack of grain insects. Farmers should therefore grow a variety of corn that develops a long tight shuck.

Newly harvested small grains should not be stored unthrashed for any length of time, as in this condition they are very susceptible to infestation. If promptly thrashed and stored in deep bins, only a thin layer on top of the bin is likely to become infested. Corn may be stored in the shuck if the husk is long and tight and fully covers the tip, but all ears with loose, broken, short, or damaged husks should be shucked and stored separately.

Clean grain should never be stored in old bins, granaries, or storehouses until they have been thoroughly cleaned and freed from the accumulations of waste grain and other materials harboring grain insects. Timbers in bins, granaries, or holds of ships that have become infested with grain insects should be destroyed or treated before being used again. Steel or concrete bins are highly desirable owing to the ease with which they are cleaned.

Bags of all kinds that have previously held grain should not be allowed in granaries or warehouses or be refilled until they have been sterilized by heat or otherwise freed from insects. The use of tight cribs will keep the grain free from infestation by insects that might fly in from the outside.

THE TREATMENT OF INFESTED GRAINS.

Insects infesting stored grain can be destroyed by the use of heat, or by fumigation with poisonous gases. These remedial measures are mentioned only briefly in this bulletin.

HEAT.

A temperature of 120° to 130° F., maintained for a short time, will kill all stages of grain-infesting insects, without injuring the germinating quality of the grain. Owing to the difficulty of subjecting the grain to such a temperature this method of control is used chiefly by millers and large grain dealers who are equipped with commercial driers suitable for the purpose.

FUMIGATION.

Carbon disulphide, carbon tetrachloride, and hydrocyanic-acid gas are the fumigants in most common use to-day for treating infested grain. All things considered, carbon disulphide is the most effective for treating grain in bulk. It is purchased as a liquid, which vaporizes, forming a gas heavier than air. If applied at the top of a gas-tight bin of grain, the gas will penetrate down through the grain, killing the insects without injury to the grain, provided it is dry. Carbon disulphide has one great disadvantage in that its gas is highly inflammable and will explode when mixed with air in certain proportions if fire in any form is brought near it. Notwithstanding this fire hazard, which must always be taken into consideration, carbon disulphide is in general use on farms for the protection of grain in cribs (see U. S. Department of Agriculture, Farmers' Bulletins 799 and 1029).

Carbon tetrachloride is not so effective as carbon disulphide and fumigation with it costs from two to three times that of fumigation with carbon disulphide, since more of the liquid must be used for the same space. Carbon tetrachloride is not particularly effective at the lower ranges of temperature (60 to 75° F.) suitable for fumigation. Fumigation with this material has, however, the great advantage of removing the fire hazard, as carbon tetrachloride is not inflammable and does not explode in the presence of fire.

Hydrocyanic-acid gas is not of value in fumigating bulks of grain. When grain is stored in sacks in warehouses heavy doses of this gas (from 2 to 2½ pounds of cyanide per 1,000 cubic feet of space) will control grain pests under favorable conditions. This method of fumigation is discussed in Department Bulletin 872.

The ethyl acetate-carbon tetrachloride mixture, a new fumigant first recommended for the treatment of bulk grain in 1924, is valuable in that no fire hazard appears to be associated with its use. Although it appears that it can be used with safety in elevator bins and elsewhere, the experience with it during the season of 1925 has not been especially favorable, and unless a better grade of chemicals can be obtained commercially so that odors will not be retained by the grain, this fumigant is likely to find a limited field of usefulness. For further information see Department Bulletin 1313 and write to the Department of Agriculture for latest developments.

The fumigation of bulk grain with chloropicrin is not in general use and is not at present recommended.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

December 8, 1925.

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This bulletin is a contribution from

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Stored-Product Insect Investigations	E. A. BACK, *Entomologist, in Charge.*

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FARMERS' BULLETIN 1269
Rev. Oct. 1927

STORED-GRAIN PESTS

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and
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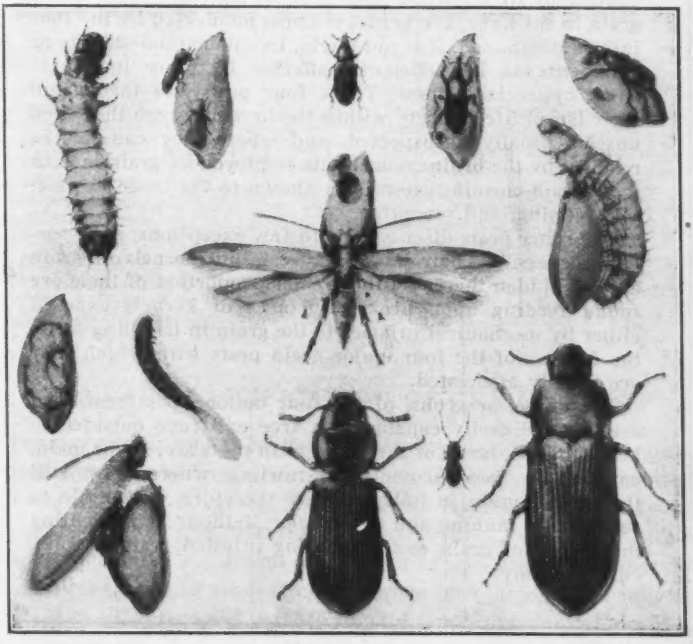

UNITED STATES
DEPARTMENT OF AGRICULTURE

U. S. GOVERNMENT PRINTING OFFICE: 1927

MOST of the damage done by insects to grain in storage and shipments is due to four species. These are the granary weevil, the rice or black weevil, the lesser grain borer or Australian weevil, and the Angoumois grain moth. Others of the 40 species or groups of species described in this bulletin can cause great damage to grain if storage conditions are unusually favorable for their increase. Yet if grain in the unbroken kernel remains unaffected by the four insects mentioned, it is not likely, in commercial storage or shipments, to be sufficiently affected by other insects to cause appreciable loss. These four pests live throughout their larval life entirely within the kernel, where they feed unseen, usually unsuspected, and where they can not be reached by the ordinary methods employed by grain men in their grain-cleaning operations known to the trade as moving, fanning, and screening.

The other pests discussed, with few exceptions, are "surface feeders." Their larvæ may eat into kernels of grain and lie hidden there, yet the greater proportion of them are found feeding upon broken surfaces of kernels exposed either by mechanical injuries to the grain in handling or by the feeding of the four major grain pests with which they are usually associated.

The larvæ, or grubs, of the four major pests mentioned are not ordinarily capable of a free existence outside the kernel but the larvæ of the other grain pests are, in the main, capable of free locomotion, crawling where they will throughout grain in bulk, and are therefore susceptible to removal by fanning and screening. Methods of preventing infestation of grain and of treating infested grain are discussed briefly.

Washington, D. C. Issued April, 1922; revised October, 1927

STORED-GRAIN PESTS.

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POPULAR CLASSIFICATION OF GRAIN PESTS.

Since the establishment of the Federal standards for grain under the provisions of the Grain Standards act, Federal grain supervisors and federally licensed grain inspectors are required to identify the various species of "live weevils and other insects injurious to stored grain" which may be present in the grain, and uniform names for grain insects should be used. Such uniform terminology will indicate definitely to all interested persons, including shipper, purchaser, and elevator operator, the exact nature of the insect found. Of the four major pests, the granary weevil, the rice or black weevil, and the lesser grain borer may be well called "grain weevils." The fourth of the major pests, the Angoumois grain moth, so destructive to wheat and corn, may be called "grain moth." Other insects likely to be found in any lot of grain may be called simply "beetles," "moths," and "mealworms," for their presence usually does not indi-

cate a condition likely to affect the trade, provided that after the grain has reached the elevator it is screened and fanned to remove these insects.

The writers have divided the insects discussed in this bulletin into grain weevils, grain borers, grain moths, flour moths, mealworms, grain and flour beetles, psocids, and mites. In some respects this is not a satisfactory grouping, especially for the insects listed as "grain and flour beetles," but it has the advantage of definitely placing the most serious insects troublesome in bulk grain.

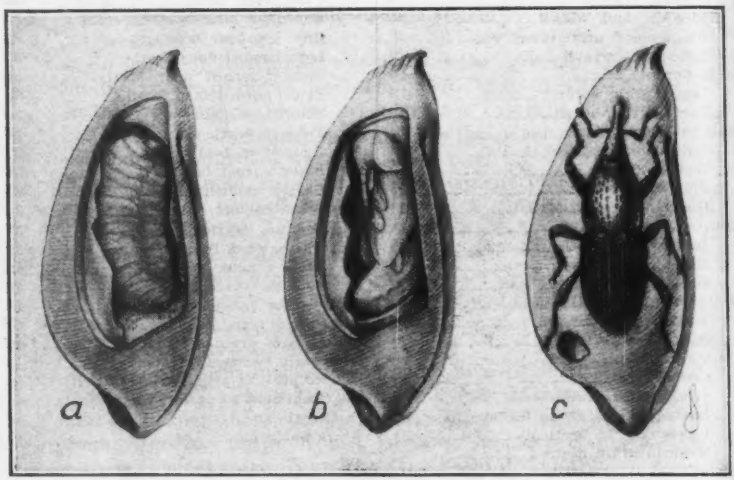

FIG. 1.—Life stages of the granary weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult. Note hole in kernel made by the adult in order to leave the seed, and hole that it is eating into the kernel for the purpose of laying eggs. This weevil closely resembles the rice weevil but has no papery wings beneath its wing covers, and the dot-like punctures on the back behind its head are elongate rather than round.

GRAIN WEEVILS.

Of the four true weevils that attack grain in the United States only two are of primary importance at present, the granary weevil and the rice or black weevil. The broad-nosed grain weevil and the coffee-bean weevil are of minor importance except locally. These four weevils have an elongated beak or snout, as shown in the illustrations, though the beak of the coffee-bean weevil is greatly reduced.

GRANARY WEEVIL.[1]

The granary weevil (fig. 1) is a small, moderately polished, chestnut brown or blackish beetle with head prolonged into a long slender snout at the end of which are a pair of stout mandibles or jaws. It is

[1] *Sitophilus granarius* L.

not more than three-sixteenths of an inch long, and often smaller. It has no wings under its wing covers and the thorax is well marked with longitudinal punctures, two characteristics that distinguish it from the closely related rice weevil, with which it is often found associated. The well-grown footless whitish grub or larva and the pupa are shown at *a* and *b*, respectively, in figure 1. The granary weevil is one of the oldest known insect pests, is a universal feeder upon grains, and is cosmopolitan, having been carried by commerce to all parts of the world. It prefers a temperate climate and is more frequently found in the Northern States than in the South.

Both adult and larva feed voraciously on a great variety of grains. The adult weevils may live for 10 or more months, and during this period each female may lay from 200 to 300 eggs. Before laying her eggs the female bores a small hole in the grain berry with her snout. When this is made she turns about and lays in it an egg, which she then covers with a gelatinous fluid which seals the hole. The small white fleshy and legless grubs that hatch from the eggs burrow about inside the kernel. When full grown, the grub transforms to the pupa stage and then into the adult weevil. In warm summer weather the granary weevil requires about four weeks to pass through the egg, larva, and pupa stages and emerge as an adult of the succeeding generation. The period of development may be prolonged greatly by cold weather.

RICE OR BLACK WEEVIL.[3]

The rice or black weevil is a small snout-beetle which varies considerably in size but rarely measures more than one-eighth of an inch in length (figs. 2 and 3). It varies in color from reddish brown to nearly black and is usually marked on the back with four light reddish or yellowish spots. It closely resembles the granary weevil in form, but it has well-developed wings beneath its wing covers, differs in color and markings, and has the thorax densely pitted with round, instead of longitudinal punctures. Figure 2 gives a good impression of the appearance of the rice weevil and its earlier stages.

This weevil has been known from early times. It is found in all parts of the world where grain is used and is one of the very worst pests in stored grain. It is particularly abundant in warm countries, where it breeds continuously and rapidly destroys all unprotected grain. Throughout the South it causes tremendous losses to corn (figs. 4, 5, 6, and 7) and is the commonest of the serious pests of commercial grain shipments.

The adult weevil lives, on an average, four or five months, each female laying between 300 and 400 eggs during this period. The

[3] *Sitophilus oryza* L.

early stages are almost identical in habit and appearance with those of the granary weevil and need not be further described. The rice

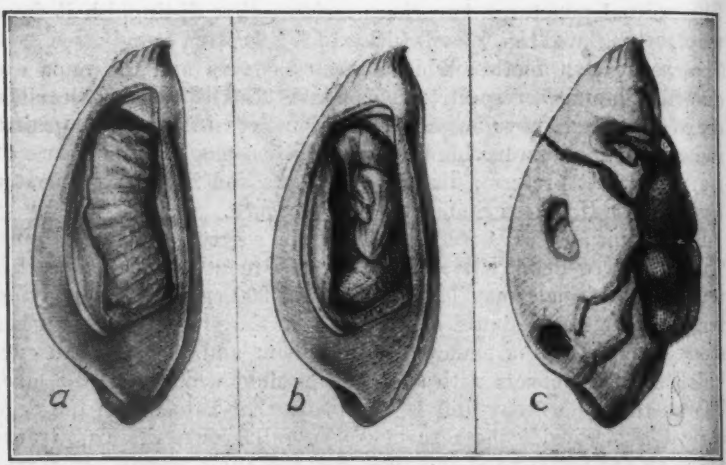

FIG. 2.—Life stages of the rice or black weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult feeding upon kernel. Note in *c* the hole in lower portion of kernel made by the adult on leaving the seed, and at two points higher up shallow holes made by the adult in feeding upon the seed after emergence. The adult weevil is at once distinguished from the granary weevil, shown in figure 1, by the four light reddish brown or yellow spots on its wing covers, by the possession of wings beneath the wing covers, and by the many rounded punctures on the back behind its head.

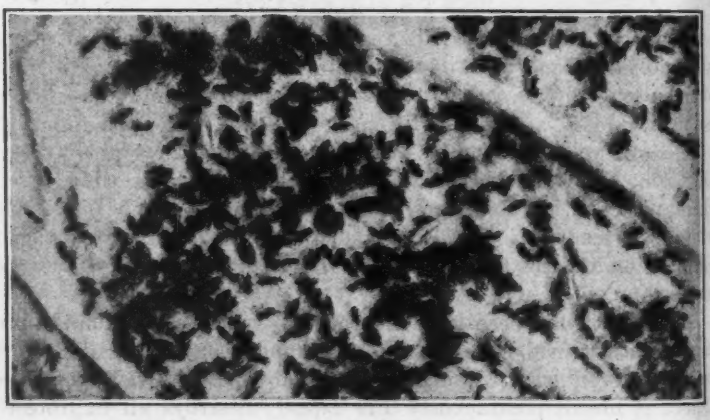

FIG. 3.—The rice or black weevil: Many adult weevils caught in the mesh of a cloth sack containing pearled barley. Compare their size with that of the barley kernels. Adult weevils when disturbed usually "play possum," but if spread upon a cloth in the sun the live ones will soon show signs of life.

weevil is a strong flier. The adults fly from granaries to the fields of grain and there start the infestation that often proves so disastrous after the grain has been harvested. During summer weather

FIG. 4.—Ear of corn with a poor, loose shuck. It is badly infested with rice or black weevils. As the adult weevils feed, they push from the kernels the chewed-up portions, frass, etc., and this material, resembling white dust, collects in larger quantities between the kernels and the shuck, or, if the ears are shucked, it falls like powder onto any object below the ear. (Back.)

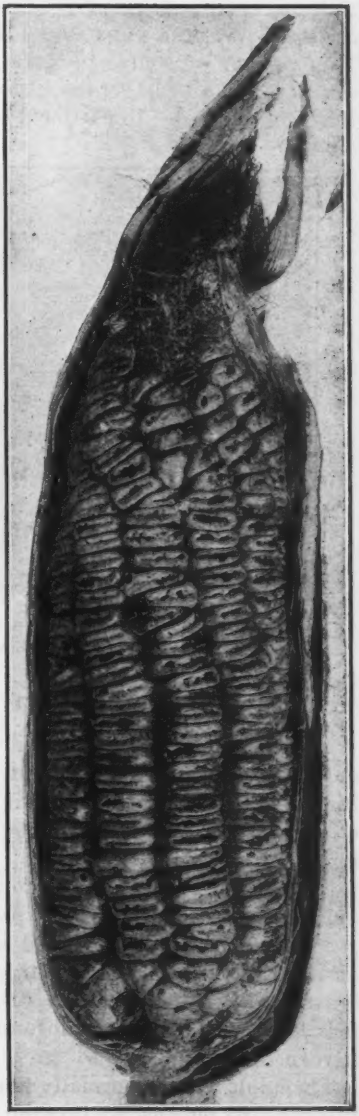

FIG. 5.—An ear of corn badly damaged by rice or black weevils. This ear has been hit against a table to jar loose the powdery substance, sometimes called the farinaceous material, and so reveals the great damage done by the weevils. The kernels of the ear have been reduced to powder and shell. (Back.)

the egg, larva, and pupa stages may be passed in as few as 26 days. This period, of course, is greatly prolonged during cool or cold weather. For a further discussion of this pest see Farmers' Bulletin 1029, United States Department of Agriculture.

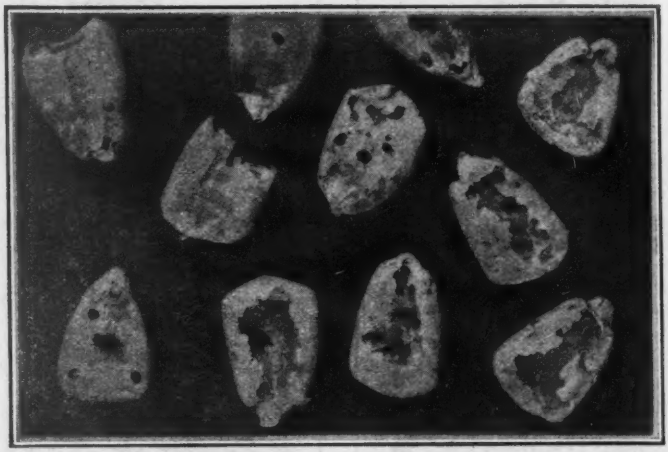

FIG. 6.—Kernels of corn taken from badly infested ear corn, showing how the rice or black weevils can thoroughly destroy all parts of the kernels. (Back.)

BROAD-NOSED GRAIN WEEVIL.[3]

The broad-nosed grain weevil is a small dark-brown snout-beetle slightly less than one-eighth of an inch long. In form and color it resembles the granary weevil somewhat but differs from it and other grain-infesting weevils by having a short, broad snout (see figure 8.)

This weevil is occasionally found in Georgia and South Carolina and is wide-spread in Florida, where it is a serious pest of stored grains. It is unable to breed in dry, hard, uninjured grain, but attacks soft or damaged grain, or grain that has been attacked by other grain insects. It is a strong flier, and, like the rice weevil, flies to the cornfields and infests the grain before it becomes fully hardened.

The adult weevils normally live for about five months, and during this time the females lay between 200 and 300 eggs. The small white eggs are usually laid in broken portions of the grain. They hatch in a few days, and the small, white, legless grubs feed on the softer portions of the grain until they become fully grown. They then change to a white pupal form which in a few days transforms to the

[3] *Caulophilus latinasus* Say.

adult beetle and cuts its way out of the grain. The period from egg to adult in summer is about one month.

FIG. 7.—Slip-shuck corn showing holes eaten through the shuck by the rice or black weevil. These holes make passages through which all kinds of grain pests move back and forth to bring about a more speedy destruction of the kernels. (Back.)

COFFEE-BEAN WEEVIL.[4]

The coffee-bean weevil is a very active, robust beetle from two-sixteenths to three-sixteenths of an inch long; dark brown in color, clothed with a mottled light and dark-brown pubescence. It may be easily recognized from the accompanying illustration (fig. 9).

This weevil is found in many countries and is extremely abundant in the Southern States, where it breeds in dried fruit, coffee berries, cornstalks, corn, and the seed and seed pods of an almost endless variety of plants. It is a strong flier and is frequently to be seen in the cornfields of the South on the exposed and damaged ears. It lays its eggs in the soft kernels of corn and breeding continues after the corn has been harvested and placed in storage. It does not cause much damage to corn in storage, as the corn becomes too hard to be attractive. It may, however, be very abundant locally in corn in Florida during the first three months of storage, and has been reported as completely destroying a sack of kafir seeds in Honolulu. Taking the country at large, the coffee-bean weevil is a very minor grain pest. Figure 10, *a* and *b*, shows the rather characteristic holes cut in the kernels of corn and in corn shucks by the larvæ and emerging adults.

[4] *Araecerus fasciculatus* DeG.

GRAIN BORERS.

Two species of grain borers are now established in the southern States. The *lesser grain borer* bids fair to become a very serious

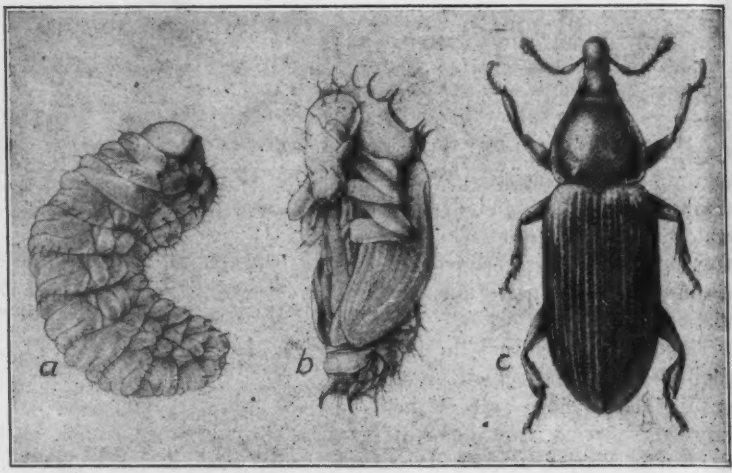

FIG. 8.—The broad-nosed grain weevil: *a*, Full-grown larva; *b*, pupa; *c*, adult weevil. This weevil is not found in northern-grown grains. It is now present in the southeastern Gulf States. The adult weevil is slightly less than one-eighth of an inch long. It is distinguished from the rice and granary weevils by its much shorter beak.

pest of grain throughout the South. The *larger grain borer* has not yet become a factor in commercial shipments of grain.

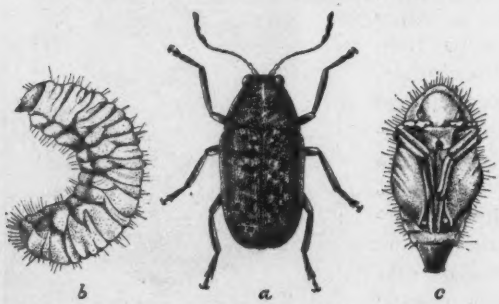

FIG. 9.—The coffee-bean weevil: *a*, Adult; *b*, well-grown larva; *c*, pupa. The adult is about three-sixteenths of an inch long, of a dark brown color covered with a light and dark brown hairiness. (Chittenden.)

LESSER GRAIN BORER.[5]

The lesser grain borer, known to many grain dealers more popularly as the "Australian wheat weevil," because of the large supplies of wheat infested by it that reached this country from Australia during the war, is one of the smallest beetles injurious to grain in this country. It appears to be steadily spreading throughout the South, and infested grain

[5] *Rhizopertha dominica* Fab.

has been found in Texas, Kansas, Oklahoma, Louisiana, Florida, and California, besides at many points of entry. It is readily distinguished from other grain pests by its slender cylindrical form and small size. It is a polished dark brown or black in color, with a

FIG. 10.—Work of the coffee-bean weevil: *a*, Holes made in corn shucks by the adult weevils eating their way out from the kernels beneath; *b*, two kernels in which larvæ of this insect have developed. Note that a single larva devours a large portion of a single kernel, which is not true of the rice weevil.

somewhat roughened surface, about one-eighth of an inch long and one thirty-second of an inch wide. Its head is large, prominent, and bent down under the thorax. The larva, pupa, and adult stages are illustrated in figure 11. It belongs to a family[6] of beetles that have

[6] Bostrychidae.

the head turned down under the thorax and are armed with powerful jaws with which they can cut directly into wood. Originally native

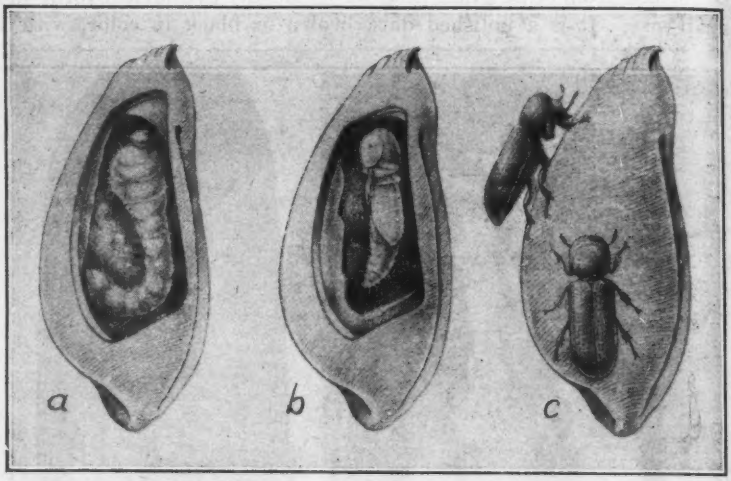

FIG. 11.—The lesser grain borer in wheat kernels: *a*, The well-grown larva; *b*, the pupa; *c*, two adult weevils. Adult borer is shiny roughened dark brown or black, about one-eighth of an inch long.

to the tropics the lesser grain borer has spread through commerce to all parts of the world.

Both beetles and larvæ cause serious damage in warm climates, attacking a great variety of grains. The destruction of which they

FIG. 12.—Kernels of wheat thoroughly riddled and devoured by the boring and feeding of the lesser grain borer and its larva. Such damaged kernels are always surrounded by much powder or flour-like material which the insects have chewed up and pushed out from the kernels.

are capable is shown by the wheat kernels of figure 12, which are literally riddled by the boring adults and their young. The females

lay from 300 to 500 eggs each, dropping them singly or in clusters in the loose grain. The eggs hatch in a few days and the small whitish grubs crawl actively about the grain, feeding on the flour produced by the boring of the beetles, or boring directly into grains that have been slightly damaged. They complete their growth within the grain, transform to white pupæ, and in time change to adult beetles which cut their way out of the grain. The period from egg to adult in summer is said to be about a month.

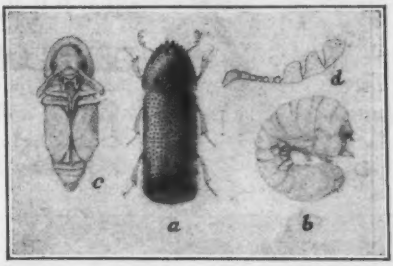

FIG. 13.—The larger grain borer: *a*, Adult insect; *b*, larva; *c*, pupa; *d*, antenna of adult. Adult borer is shiny polished dark brown, about one-sixth of an inch long. *a*, *b*, *c*, About six times natural size; *d*, highly magnified. (Chittenden.)

LARGER GRAIN BORER.[7]

The larger grain borer is a small, dark brown, elongate-cylindrical beetle about one-sixth of an inch long. As may be seen in figure 13, it is very similar in appearance to the lesser grain borer, but may be distinguished by its larger size and comparatively smooth, polished surface.

This beetle is a tropical insect not as yet widely distributed in this country. It is occasionally found infesting corn (fig. 14) in the Southern States. Its habits are similar to those of the lesser grain borer. It, also, has probably acquired its grain-feeding habits rather recently.

FIG. 14.—Kernel of corn showing work of adult of larger grain borer. The adult borers tunnel in all directions and reduce kernels to powder and shells. Enlarged. (Chittenden.)

GRAIN MOTHS.

The grain moths include only those moths capable of destroying sound, unbroken grain kernels. They are not so abundant as the flour moths, which are principally pests in broken, damaged kernels or milled products.

ANGOUMOIS GRAIN MOTH.[8]

The Angoumois grain moth is a small buff or yellowish brown moth with a wing expanse of about one-half inch. This is the moth most commonly found in infested grain in this country and is not likely to be confused with any other. It attacks all cereal grains, is found in all parts of the world, and is particularly injurious in the South, where it attacks grain both in the field and in storage.

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[7] *Dinoderus truncatus* Horn. [8] *Sitotroga cerealella* Oliv.

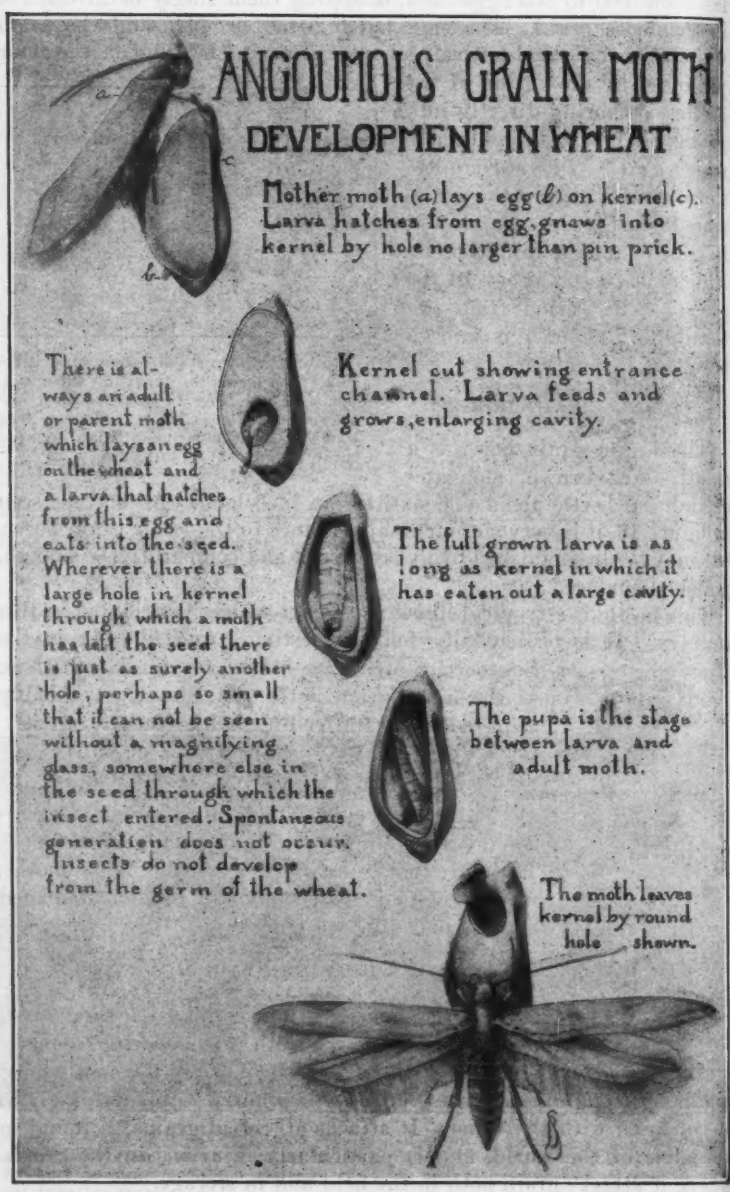
ANGOUMOIS GRAIN MOTH
DEVELOPMENT IN WHEAT
Mother moth (a) lays egg (b) on kernel (c). Larva hatches from egg, gnaws into kernel by hole no larger than pin prick.
There is always an adult or parent moth which lays an egg on the wheat and a larva that hatches from this egg and eats into the seed. Wherever there is a large hole in kernel through which a moth has left the seed there is just as surely another hole, perhaps so small that it can not be seen without a magnifying glass, somewhere else in the seed through which the insect entered. Spontaneous generation does not occur. Insects do not develop from the germ of the wheat.
Kernel cut showing entrance channel. Larva feeds and grows, enlarging cavity.
The full grown larva is as long as kernel in which it has eaten out a large cavity.
The pupa is the stage between larva and adult moth.
The moth leaves kernel by round hole shown.

FIG. 15.—Life cycle of Angoumois grain moth on wheat. (Back.)

Each female moth may lay as many as 150 eggs, which are white when first laid but soon change to a reddish color. The eggs are laid on or near the grain. Upon hatching, the minute white larva or caterpillar bores into a kernel of grain and begins feeding on the contents. When full grown it eats out a channel to the outside of the seed but leaves a thin layer of the seed coat intact. It then changes to a reddish brown pupa, and later the adult or moth emerges, pushing aside the thin section of seed coat that covers the exit from the channel. The development from egg to adult may be completed in five weeks. Figures 15 and 16 show the successive stages in the development of

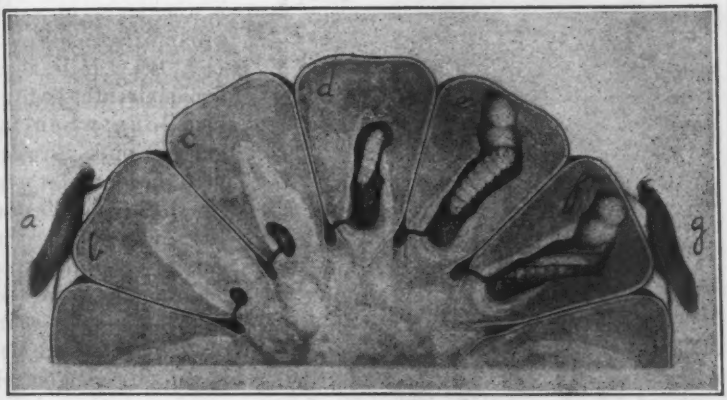

FIG. 16.—Cross section of ear of corn showing development of Angoumois grain moth in corn. The newly hatched larva crawls down to the germ end of the corn and begins feeding upon the soft germ. As it grows older and stronger it eats out into the firmer portion of the kernel and finally, in most instances, eats to the outer end. (Back.)

this insect in a kernel of wheat and of corn from the time the egg is laid until the adult appears. In figure 17 is shown an ear of corn with the external evidence of heavy attack, and in figure 18 are shown wheat kernels with the emergence holes of the moth. For a further discussion of this pest see Farmers' Bulletin 1156, "The Angoumois Grain Moth."

WOLF MOTH.[9]

The wolf moth is a small moth about the size of the Angoumois grain moth, creamy white and thickly mottled with brown. The mottled appearance distinguishes it from the Angoumois grain moth. It infests all kinds of grain, both in the field and in storage. The larva feeds on the grain and webs the kernels together.

[9] *Tinea granella* L.

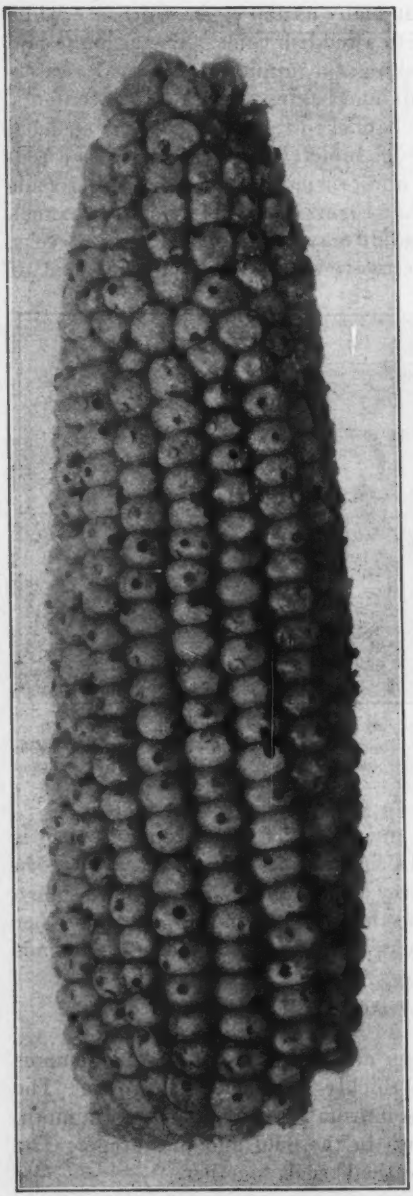

FIG. 17.—Ear of popcorn showing heavy infestation by the Angoumois grain moth. Note that certain of the kernels have three emergence holes, and that many have served as food for two moths. The development of a single insect in a kernel causes a loss of from 13 to 24 per cent in weight.

The wolf moth is distributed throughout the Northern States but is not very abundant and can not be compared with the Angoumois grain moth for destructiveness.

PINK CORNWORM.[10]

The pink cornworm is the larva or caterpillar of a small moth (fig. 19). It is about five-sixteenths of an inch long when full grown; pink in color, with head and thoracic shield pale brown. Figure 20 gives a good idea of its appearance. The moth which develops from this worm or larva is smaller than the Angoumois grain moth, with a wing expanse of slightly less than half an inch. The forewings are banded and mottled with yellow, reddish brown, and black, as shown by figure 19. The pale grayish hindwings are very slender and are edged with long fringes. The pupa is shown in figure 21.

This insect is common in the South, where it causes considerable injury to

[10] *Pyroderces rileyi* Wals.

corn, both in the field and in storage. Infestation begins in the field and is continued after the corn is placed in storage. The very characteristic injury is shown in figures 22 and 23. The large amount of frass that is loosely webbed together and fills the interstices between the kernels or is crowded into the cavities of kernels that have been eaten out is a reliable indication of the presence of this pest. The pearly white eggs are laid singly or occasionally in twos or threes. The pinkish larvæ feed on the seed, husk, and cob with equal relish. Though capable of serious injury to corn, in particular as it comes

FIG. 18.—Kernels of wheat showing the small round emergence holes that prove that the Angoumois grain moth has developed in the seed, thus reducing the weight somewhat over 50 per cent. (Back.)

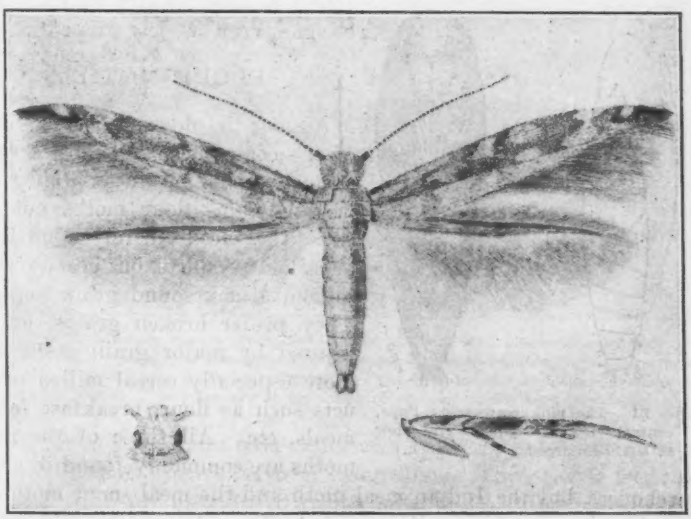

FIG. 19.—The pink cornworm: Moth, much enlarged; head and leg more enlarged. The moth has a wing spread of a little less than half an inch. (Chittenden.)

to maturity in the field, and while in the cribs on Southern farms, the pink cornworm is seldom a serious pest of commercial shipments.

RICE MOTH.[11]

The rice moth has a wing expanse of about half an inch and is of a pale grayish brown or tawny color. Its characteristic appearance is shown in figure 24. The larva (fig. 25) resembles somewhat that of the Indian meal moth, being when full grown about half an inch

FIG. 20.—The pink cornworm: Full-grown larva, side view, greatly enlarged. When full grown the larva is pink and about five-sixteenths of an inch long. (Chittenden.)

long and varying in color from white to a dirty, slightly bluish gray with occasional tints of green. Damage by the pest, as in the case of all moth pests, is done by the larvæ, which feed upon rice, cocoa, chocolate, ships biscuits, etc. The larvæ produce a dense webbing as they become well grown. When feeding upon grains they spin dense silken tubes, webbing the grain kernels into the walls of the tubes. The pupa is shown in figure 26. The rice moth is seldom found in this country and has not become very widely disseminated.

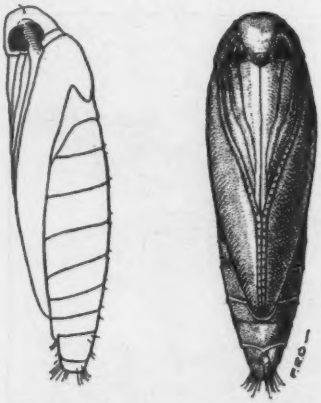

FIG. 21.—The pink cornworm: Pupa, ventral view at right, lateral view at left. Enlarged. (Chittenden.)

FLOUR MOTHS.

Among the flour moths are some of the commonest and most serious pests of grain products. They are designated as flour moths not because they feed entirely upon flour or milled products, but because they seldom attack sound grain kernels. They prefer broken grains, grains injured by major grain pests, and more especially cereal milled products such as flour, breakfast foods, meals, etc. All three of the flour moths are commonly found in grain warehouses, but the Indian meal moth and the meal snout moth are probably the most frequently reported. These two moths may, under specially favorable conditions, become established in whole grain and other seeds and cause injury especially by eating out the germ.

[11] *Corcyra cephalonica* Staint.

INDIAN MEAL MOTH.[12]

The Indian meal moth is a rather handsome moth with a wing expanse of nearly three-fourths of an inch. It is easily distinguished from other grain pests by the peculiar marking of its forewings. These are reddish brown with a coppery luster on the outer two-thirds, but whitish-gray on the inner or body end. Moths and larvæ are shown in figure 27. The female moths lay from 300 to 400 eggs,

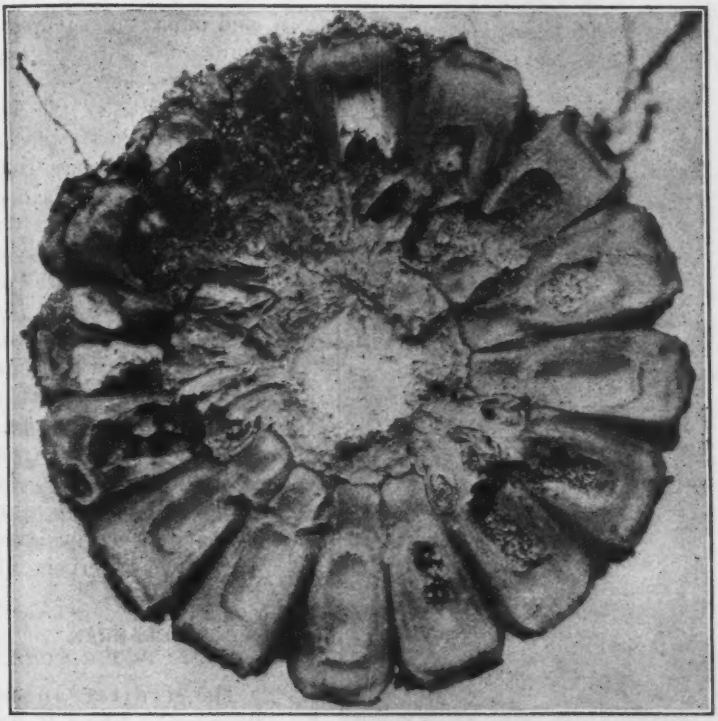

FIG. 22.—Ear of corn cut to show characteristic feeding and destruction by pink corn-worm larvæ. Note that the larvæ eat from one kernel to another, often severing the kernels from the cob. The larvæ sometimes eat into the cob and there transform to the pupa stage. The pupæ are about one-third as long as the kernels shown.

singly or in groups, on food material. The eggs hatch within a few days into small whitish larvæ or caterpillars. These larvæ feed upon grains, grain products, dried fruits, nuts, and a rather wide variety of foodstuffs. When full grown, the larvæ are about half an inch long, dirty white in color, varying sometimes to greenish and pinkish hues. A full-grown larva is shown in figure 28, clinging to a kernel

[12] *Plodia interpunctella* Hbn.

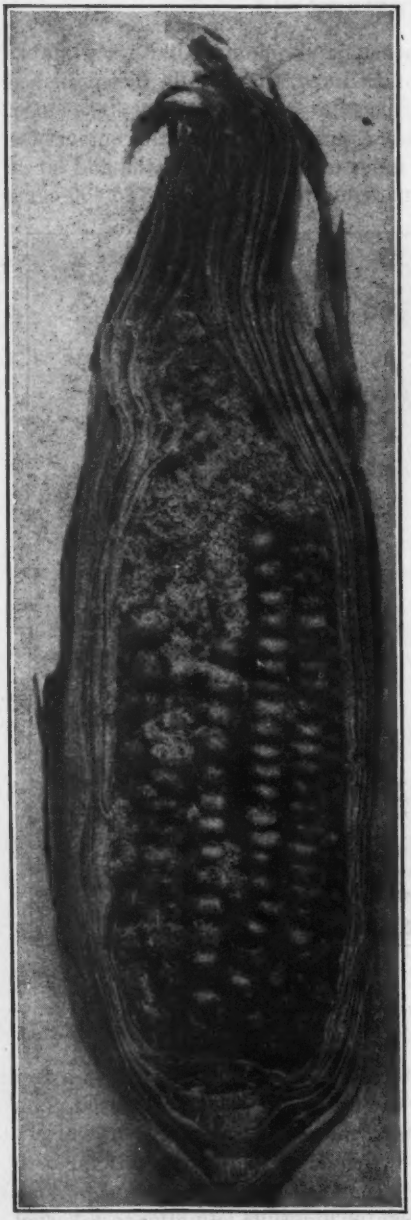

FIG. 23.—Ear of corn with portion of shuck removed to show surface feeding by larvæ of the pink cornworm. Often many kernels drop from the ear when the shucks are removed because of the feeding of the pink cornworm larvæ.

of wheat. This larva spins a silken cocoon and transforms to a light-brown pupa from which the parent moth later emerges. The Indian meal moth may pass through its egg, larva, and pupa stages in about four weeks—during warm weather.

The larva of the Indian meal moth spins a web as it becomes full-grown, and leaves behind a silken thread wherever it crawls. When sacks of cracked corn, meal, or corn in the ear that has been previously injured by other pests become heavily infested, this webbing often is sufficiently abundant to attract attention. The loosely clinging web shown on the ear of corn in figure 29 is characteristic of this pest.

MEDITERRANEAN FLOUR MOTH.[12]

The Mediterranean flour moth has a wing spread of slightly less than one inch. Its hind-wings are a dirty white, but its forewings, which alone show when the moth is not flying, are a pale leaden gray with transverse wavy black markings. (See fig. 30.)

[12] *Ephestia kuehniella* Zell.

The Mediterranean flour moth is a native of Europe. Its first discovery in the United States was in California in 1892. Since then it has spread to practically all the States of the Union and is recognized as the most serious pest of flour mills, owing to the silken threads

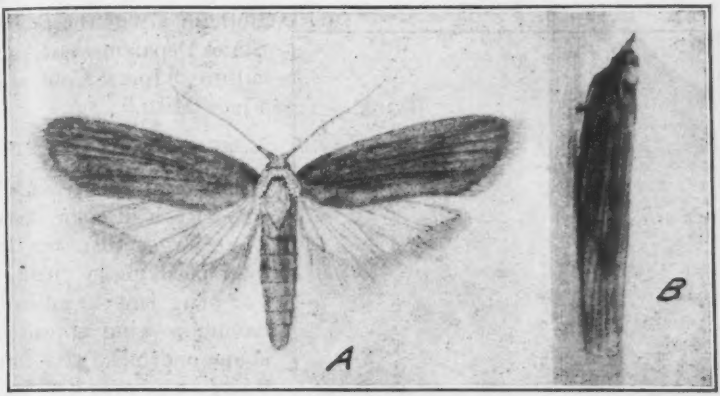

FIG. 24.—The rice moth: *a*, Mature moth, dorsal view, with wings spread; *b*, side view of same moth with wings folded about body. The moth is of a grayish brown or tawny color, with a wing spread of about half an inch. Much enlarged. (Chittenden.)

which the larvæ spin wherever they crawl. These webs mat the flour or meal together and eventually clog machinery so that mills have to shut down for a thorough cleaning and treatment. Although preferring flour and meal, the Mediterranean flour moth attacks grain, bran, and cereal products and is commonly found in storehouses and granaries.

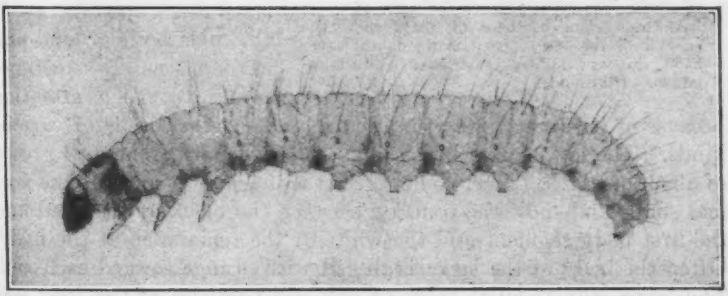

FIG. 25.—Full-grown larva of the rice moth. The full-grown larva is about one-half inch long, and is of a whitish or bluish gray color. Much enlarged. (Chittenden.)

The female moth lays small white eggs in accumulations of flour, meal, or waste grain. From the eggs the small larvæ hatch in a few days. When full grown, these are about half an inch long and are of a whitish or pinkish color with a few small black spots on the body.

The full-grown larva spins a silken cocoon in which the insect transforms to a reddish-brown pupa. Later the parent moth emerges from the pupa. During warm weather, the Mediterranean flour moth requires about nine weeks to pass through its egg, larva, and pupa stages. A more complete discussion of this pest will be found in Bulletin 872 of the United States Department of Agriculture, "Insect Control in Flour Mills."

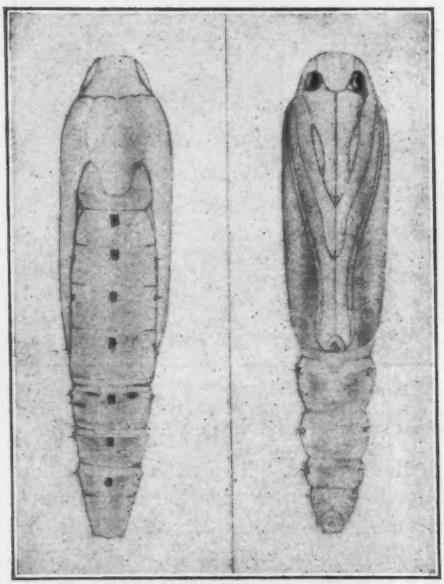

FIG. 26.—Pupa of the rice moth: At left, dorsal view; at right, ventral view. The pupa is found in a dense tough cocoon into the walls of which have been spun particles of the food. The cocoons of the Indian meal moth, on the other hand, are very loosely constructed. Much enlarged. (Chittenden.)

MEAL SNOUT MOTH.[14]

The meal snout moth is brownish in color, somewhat larger than the Indian meal moth, though varying in size, usually having a wing spread of about one inch. Its forewings are marked in a characteristic pattern indicated in figures 31 and 32; they are light brown with dark brown patches at base and tip and each with two wavy transverse white lines. The meal snout moth is widely distributed and a general feeder in the larva stage upon cereals of all kinds both ground and in the berry. It sometimes attracts much attention because of its capacity to web up and bind together seeds of various kinds. The larvæ are whitish and attain a length when full grown of about one inch. The two larger larvæ of figure 31 indicate the normal shape and show the contrast between the black of the head and the first body segment and the white of the remainder of the body. Often the body of the larva is tinged with orange toward each end. The larvæ spin peculiar tubes of silk and particles of the food material. They rest in these tubes, which are very tough, and feed from the openings at the ends. When full grown the larvæ leave the tubes, spin silken cocoons, often covered with food particles, and transform to the pupæ from which later emerge the adult moths.

[14] *Pyralis farinalis* L.

The meal snout moth may require only eight weeks to pass through the egg, larva, and pupa stages.

FIG. 27.—The Indian meal moth: Tip of ear of corn showing, *a*, three moths with their characteristic light and dark markings, and *b*, two well-grown larvæ. The adult moth is distinguished from all other grain-infesting moths by having the outer two-thirds of its wings brownish and the inner third whitish gray. It has a wing spread of about three-fourths of an inch.

The meal snout moth is primarily a pest of seeds that are held for some time in cool and damp localities. Outbreaks that have come to the attention of the authors have always been centered in

grain that was harvested during rainy weather or so stored that the moisture content was unusually high. Attempts to rear the moth in dry, warm laboratories have failed. The larvæ cut through burlap sacking and can damage sacks greatly when heavy infestations develop in sacked material. Figure 33 shows the characteristic webbing together of infested seeds—in this instance navy beans—and figure 32 shows the tendency for larvæ to spin their whitish silken cocoons on the outside of grain sacks where the sacks touch each other.

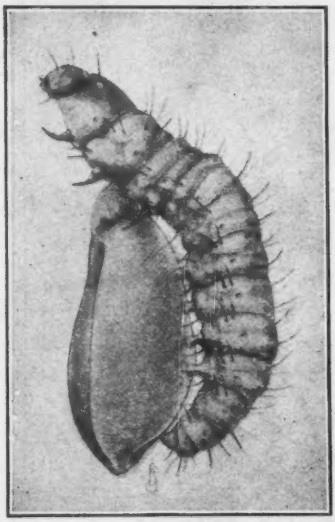

FIG. 28.—Well-grown larva of the Indian meal moth, crawling on kernel of wheat. These worms are white or greenish in color and frequently eat out the germ end of wheat. They attain a length of about half an inch.

MEALWORMS.

There are two species of mealworms in the United States. The adults are the largest of the beetles found in grain and their larvæ are conspicuous, for they attain a length of about one inch and are as large around as an earthworm.

YELLOW MEALWORM.[15]

The adult of the yellow mealworm is a polished dark-brown or black beetle, somewhat more than half an inch long, with its thorax finely punctured and with its wing covers longitudinally striated or grooved. (See fig. 34, at right.) The females lay bean-shaped white eggs covered with a sticky secretion that causes the flour, meal, or grain waste in which they are placed to adhere to them. The eggs hatch in about two weeks into slender white larvæ, which soon turn yellow and assume the form shown in figure 34. When full grown, the larvæ are about an inch long and yellowish, shading to yellowish-brown toward each end and at the articulation of each segment. The pupa into which the larva transforms before becoming an adult beetle is shown in figure 34.

The yellow mealworm is widespread over the world and is frequently found in stored grains. It belongs to a family of beetles[16] known as the darkling beetles because of their preference for dark places. The adults fly only at night. During daylight they conceal themselves, with the larvæ, beneath sacks of grain, under grain boxes,

[15] *Tenebrio molitor* L. [16] Tenebrionidae.

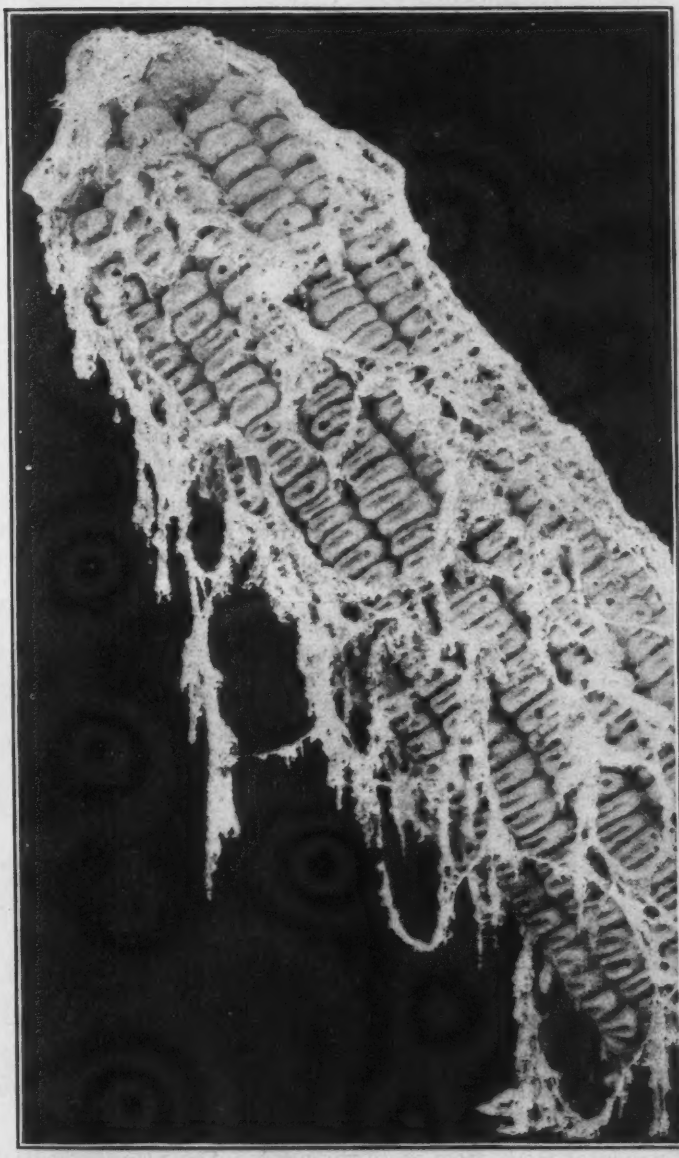

FIG. 29.—Ear of corn showing the loose webbing characteristic of the Indian meal moth larvæ. This moth rarely attacks sound grain, but, as is here shown, frequently attacks grains already injured by other grain pests. Such webbing as is here shown develops only when corn or other grains are left unmoved for some time.

or beneath grain and other food. There is but one generation each year. The adults begin to appear in the latitude of Washington during May and by June have laid most of their eggs and have died.

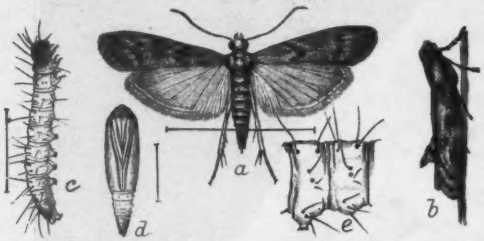

FIG. 30.—The Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa (enlarged); *e*, abdominal joint of larva (more enlarged). The adult moth, with a wing expanse of a trifle less than one inch, is leaden gray in color, marked with transverse wavy black markings. The full-grown larva is whitish or pinkish in color, with small black spots, and is about one-half an inch long. (Chittenden.)

Farther north the adults appear during June. The larvæ become full grown in about three months, but instead of transforming then to the adult stage they continue feeding and molting until cold weather and then hibernate as larvæ. The following spring they transform to the pupa stage, in which the insect passes about two weeks. Because the yellow mealworm has but one generation each year, and is entirely an external feeder upon grains, it need not be feared as a serious pest. Screening and fanning

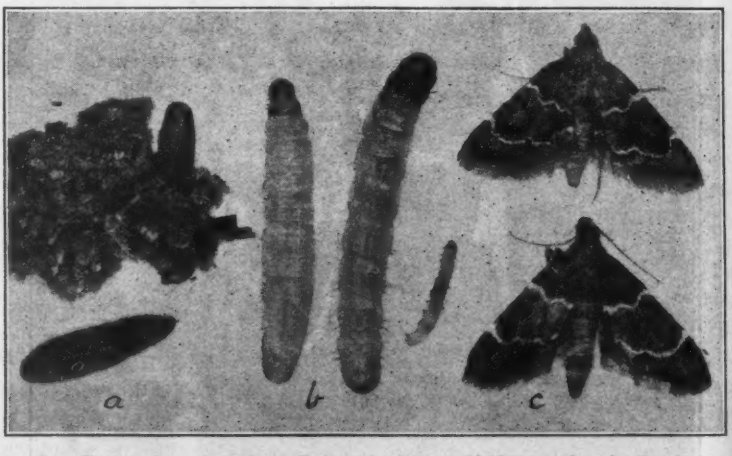

FIG. 31.—The meal snout moth: *a*, Pupa and, above, webbed mass of grain showing portion of pupa protruding; *b*, two well-grown larvæ with a smaller larva at right; *c*, two adult moths. Magnified about one and one-half times. The markings on the forewings easily distinguish this insect from other grain pests.

will remove it easily from grain shipments. The well-grown larvæ, however, can do serious injury to whole grains under certain conditions when grain is held for long periods without being moved.

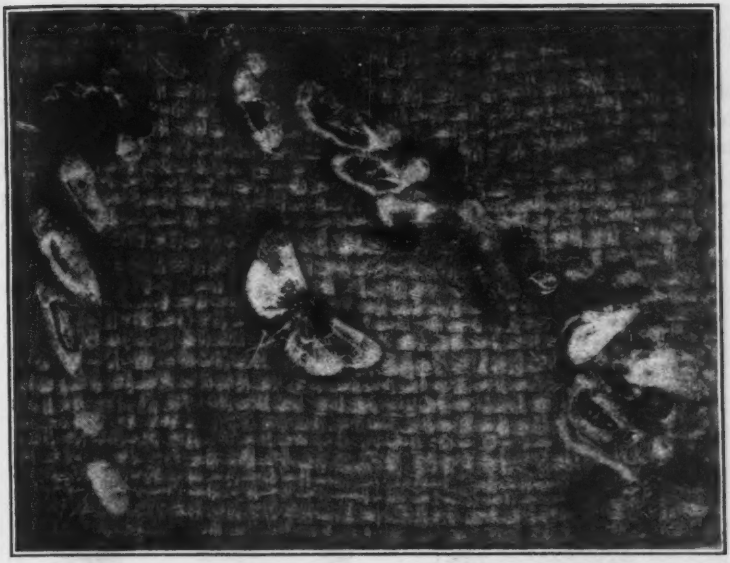

FIG. 32.—Inside of a grain sack that was filled with infested vetch seed. Note vetch seeds sticking to side of bag as a result of the webs of the larvæ of the meal snout moth, the numerous whitish cocoons with dark pupæ within, and, in the center, one adult moth. Natural size.

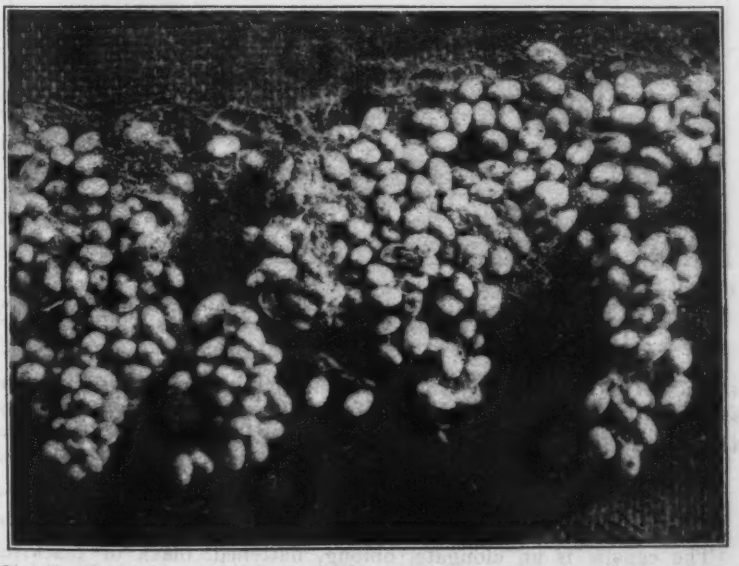

FIG. 33.—Navy beans webbed together by larvæ of the meal snout moth, and adhering to sack. The larvæ often cut sacks so seeds fall out and lodge where sacks touch each other. In these places the seeds are usually more heavily infested.

DARK MEALWORM.[17]

The dark mealworm, as may be seen by the larva, pupa, and adult shown in figure 35, is very similar in form, size, and color to the yellow mealworm, to which it is closely related. The adult beetle differs, however, in being dull pitchy black, in contrast to the shiny or polished dark brown or black of the yellow mealworm. Its larva so closely resembles the larva of the yellow mealworm that it can be distinguished most easily by its much darker color. The two

FIG. 34.—The yellow mealworm. Four well-grown larvæ, two pupæ, and the black adult beetle, with five kernels of wheat to indicate relative size. The larvæ when full grown are about one inch long and yellowish. The adult beetles are shiny black and slightly more than half an inch long.

species of mealworm are often found associated, and what has been said of the stages of the yellow mealworm applies equally well to the dark mealworm.

GRAIN AND FLOUR BEETLES.

CADELLE.[18]

The cadelle is an elongate, oblong, flattened, black or blackish beetle about one-third of an inch long. It resembles the mealworms

[17] *Tenebrio obscurus* Fab.

[18] *Tenebroides mauritanicus* L.

in appearance, but is much smaller and the thorax and abdomen are loosely joined. (See fig. 36.)

The larva of the cadelle is one of the largest of the grain-infesting insects and is easily recognized. It is about three-quarters of an inch long, fleshy, with the abdomen terminating in two dark horny points. The larva is a dirty or chalk white, with head, thoracic shield, and the two horny points at end of body black, as shown in figure 37.

This insect is widespread over the world and is frequently found in mills, granaries, and storehouses, where it infests flour, meal, grain, etc. Both larva and adult feed on grain and have the destructive habit of going from kernel to kernel and devouring the embryo.

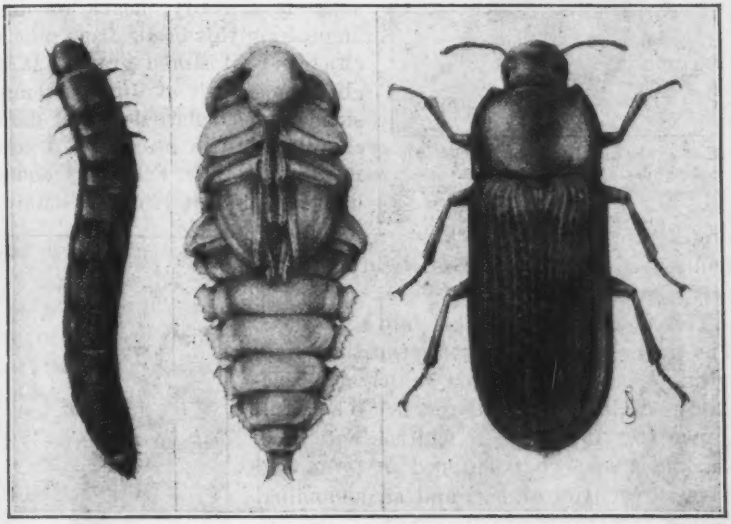

FIG. 35.—The dark mealworm: *a*, Full-grown larva; *b*, pupa; *c*, adult beetle. Distinguished from the yellow mealworm by the dark brown color of the larva and the dull, not shiny appearance of the adult beetle. For true relative size of the larva, pupa, and adult compare with figure 34.

The cadelle often becomes well established in ear corn (fig. 38) that has first been injured by the Angoumois grain moth or by the weevils. The long slits in corn kernels shown in figure 38 are characteristic of cadelle infestation. Were it not for the fact that there is not more than one generation of this insect each year the cadelle would be one of the most serious enemies of stored grain. As it is it is probably the longest lived of the insects that attack stored grain, and frequently causes severe losses.

The white eggs are laid in clusters in the food material selected and hatch in about 10 days. When the larvæ become fully grown they seek some secluded place in which to transform to the pupa (fig. 39), frequently boring into the timbers of the bin or other re-

FIG. 36.—The cadelle: Adult beetle. The cadelle is a flattened, black beetle about one-third of an inch long.

ceptacle that holds the infested material. Both larvæ and beetles feed to some extent on other grain-infesting insects, hence are partly predacious.

SAW-TOOTHED GRAIN BEETLE.[19]

The saw-toothed grain beetle gains its name from the peculiar structure of the thorax, which bears six sawtoothlike projections on each side (fig. 40). This character is a ready means of distinguishing this beetle from others that infest stored grain. It is about one-tenth of an inch long, slender, much flattened, and dark chocolate brown in color. A cosmopolitan beetle, extremely abundant at times, it is nearly omnivorous, infesting grains, flours, meals, dried fruits, seeds, etc. Both beetle and larva are very active.

The small slender eggs hatch in a few days. The emerging larvæ do not spend their lives within a single grain but crawl about actively, feeding here and there. When full grown (fig. 40), they are whitish, with dark markings, somewhat flattened in form, and have three pairs of legs and an abdominal proleg. When ready to pupate they construct delicate cocoon-like coverings by joining together small grains or fragments of foodstuffs with a sticky secretion and within this the pupa (fig. 40) and later the adult form are assumed. Development from egg to adult may take place in 24 days in summer.

FIG. 37.—The cadelle: Larva. Commonly found crawling among grain kernels. It may appear glistening white or dull and powdered according to the material in which it is crawling. When full grown it is about three-fourths of an inch long.

SQUARE-NECKED GRAIN BEETLE.[20]

The square-necked grain beetle is closely related to the saw-toothed grain beetle, which it greatly resembles in form, size, and color. It is a flattened, oblong, polished, reddish brown beetle about one-tenth of an inch long. It differs from the saw-toothed grain beetle

[19] *Oryzaephilus surinamensis* L. [20] *Silvanus gemellatus* Duv.

by having the thorax almost square in shape and lacking the sawtoothlike projections. (Fig. 41.)

This beetle is chiefly abundant in the South, where it is found in great numbers outdoors infesting the seed pods of a great variety of plants. It is one of the most common beetles in stored corn in the South and in the cornfields is always to be found on damaged or exposed ears. The immature stages closely resemble those of the preceding species both in form and in habit. The larvæ have the bad habit of devouring the germ of the seed in which they breed. They can develop from egg to adult in about three weeks.

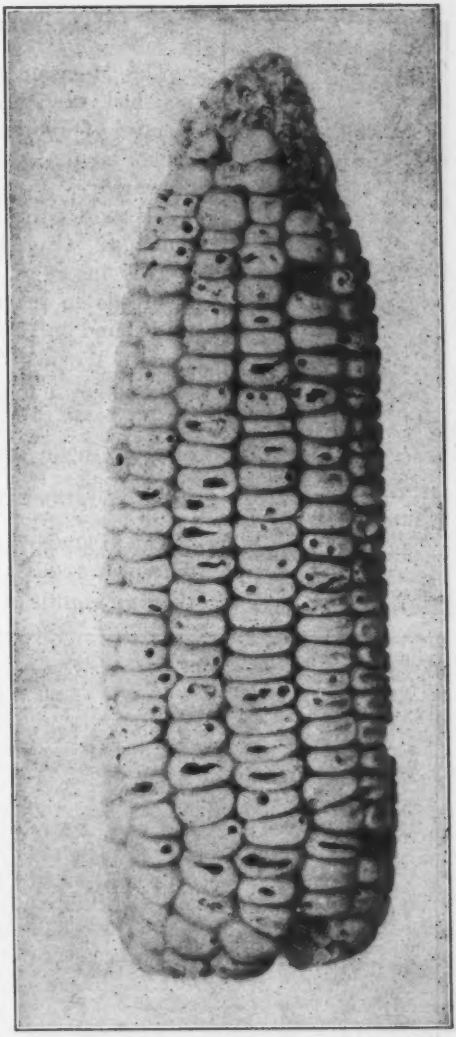

FIG. 38.—Ear of corn infested by the Angoumois grain moth (round holes in kernels) and the cadelle. The elongated slits in the kernels are characteristic of cadelle feeding and emergence. Only ear corn stored for several years will develop this evidence of cadelle attack.

FOREIGN GRAIN BEETLE.[21]

The foreign grain beetle is a small reddish brown beetle somewhat similar in appearance to the preceding species, to which it is closely related. It differs from it by being smaller and more robust. (Fig. 42.) Although of world-wide distribution, it is of little consequence as an enemy of stored grains. It is attracted to damp and moldy grains and feeds on the molds developing in such grains. It is rarely found in clean grain.

[21] *Cathartus advena* Waltl.

FIG. 39.—The cadelle: Pupa, much enlarged. The pupa is seldom seen as this stage of the cadelle's life cycle is spent in a cell made in an inaccessible place.

MEXICAN GRAIN BEETLE.[22]

The Mexican grain beetle is a highly polished, deep brown beetle about three-sixteenths of an inch long. While resembling somewhat the confused flour beetle in general appearance, it can be readily distinguished by its more polished surface and by its longer antennæ. (Fig. 43.)

This insect is common in Mexico, where it breeds in grain and grain products. It was found in this country in grain exhibits at the World's Columbian Exposition, but is not known to be permanently established in this country as yet. It may be found in grain in the extreme South.

SIAMESE GRAIN BEETLE.[23]

The Siamese grain beetle is an elongate, flattened, reddish-brown beetle slightly less than an eighth of an inch long characterized

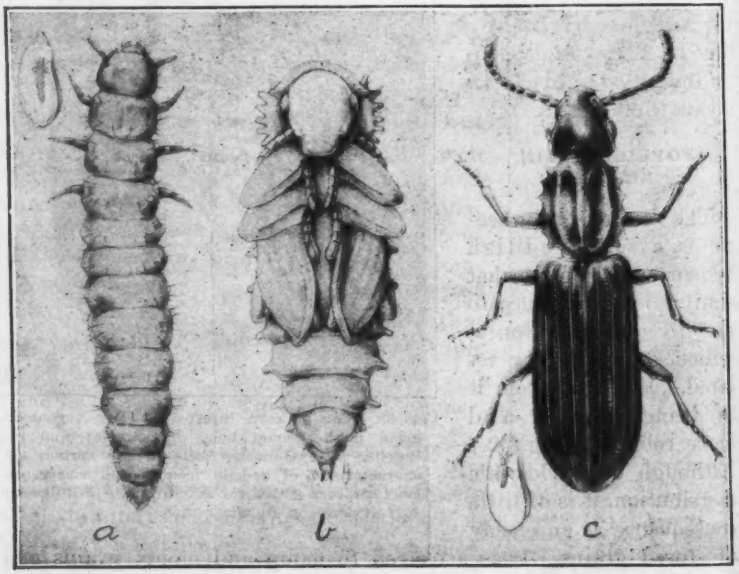

FIG. 40.—The sawtoothed grain beetle: *a*, Well-grown larva, with kernel of wheat to show its relative size; *b*, pupa; *c*, adult beetle with kernel of wheat to show its relative size. The adult beetle, about one-tenth of an inch in length, can be easily recognized by the six toothlike projections on the sides of the thorax.

[22] *Pharaconotha kirschi* Reitt. [23] *Lophocateres pusillus* Klug.

by the much flattened margins of the thorax and wing covers (fig. 44).

First appearing in exhibits of rice and cereals from Siam, Liberia, and Ceylon at the World's Columbian Exposition, it has since been reported as injurious to stored grain and grain products in South Carolina and Texas. It is likely to be found in seaport towns and in the Southern States, but as yet it is not abundant or widespread.

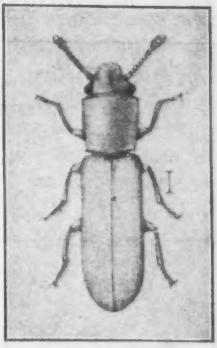

FIG. 41.—The square-necked grain beetle. (Chittenden.)

FLAT GRAIN BEETLE.[24]

The flat grain beetle is a small, flattened, oblong, reddish-brown beetle about one-sixteenth of an inch long, with elongate antennæ somewhat longer than half the length of its body. (Fig. 45.) It is readily distinguished because it is the smallest beetle commonly found in stored grain in this country. It is cosmopolitan in distribution, is very generally found in stored corn in the South, and is often screened from wheat shipments. Little is known of its habits or of its early stages, though it is thought to be a scavenger or predacious on other insects. The full-grown larvæ form cocoons of a gelatinous substance to which food particles adhere. While it is present sometimes in unbelievable numbers in grain shipments, it appears to do little damage to whole grains. The larvæ have been found destroying the germ in kernels of wheat.

FIG. 42.—The foreign grain beetle. (Chittenden.)

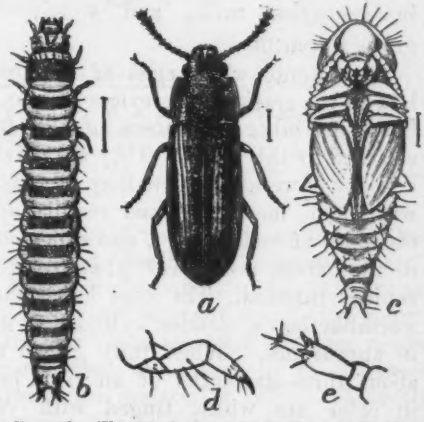

FIG. 43.—The Mexican grain beetle. *a*, Beetle; *b*, larva; *c*, pupa; *d*, leg of larva; *e*, antenna of larva. *a*, *b*, *c*, Much enlarged; *d*, *e*, more enlarged.

[24] *Cryptolestes pusillus* Schön.

CONFUSED FLOUR BEETLE.[25]

The confused flour beetle (fig. 46) is a shiny, reddish-brown beetle about one-sixth of an inch long, flattened and oval in form, with head and upper parts of thorax densely covered with minute punctures and with wing covers ridged lengthwise and sparsely punctured between the ridges. It is generally distributed over the world and is very abundant in all parts of this country. It is known as one of the flour beetles owing to its frequent occurrence in flour. It is a general feeder on starchy foods and is probably the worst insect pest of prepared cereal foods. It is constantly found in granaries, mills, and storehouses, and grain shipments.

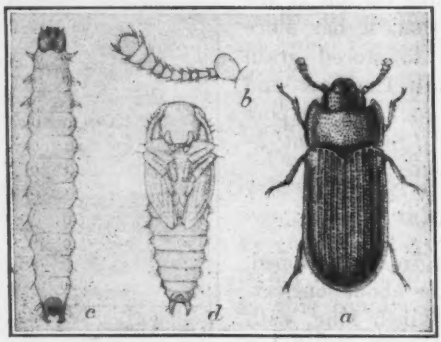

FIG. 44.—The Siamese grain beetle. *a*, Beetle; *b*, antenna of same; *c*, larva; *d*, pupa. *a*, *c*, *d*, About ten times natural size; *b*, greatly enlarged.

The minute white eggs of this beetle are laid in the cracks and crevices of bins, barrels, boxes, or other containers of the foodstuffs attacked by this insect. They are covered with a sticky secretion so that they become covered with flour, meal, etc., and readily adhere to the sides of sacks, boxes, and other containers so that fresh material placed in them is rapidly infested. The eggs hatch into small wormlike larvæ, slender, cylindrical, and wiry in appearance. When fully grown they are about three-sixteenths of an inch long, and in color are white, tinged with yellowish. These larvæ feed on flour or other material such as grain dust and the broken surfaces of grain kernels. When full grown they transform to small naked pupæ. At first white, the pupæ gradually change to yellow and then brown, and shortly afterwards transform to beetles. The period from egg to adult in summer is about four weeks under most favorable weather conditions, though the

FIG. 45.—Adult of the flat grain beetle, showing characteristic long antennæ. Not more than one-sixteenth of an inch long. This beetle is one of the very smallest found in grain shipments.

[25] *Tribolium confusum* Duv.

life cycle is greatly prolonged by cold weather, as is true of all grain pests.

RUST-RED FLOUR BEETLE.[26]

The rust-red flour beetle is almost identical in appearance with the preceding species, to which it is closely related. It can be distinguished from the confused flour beetle only with the aid of a magnifying glass. The segments of the antennæ of the confused flour beetle increase in size gradually from the base to the tip, while in the rust-red flour beetle the last few segments of the antennæ are abruptly much larger than the preceding ones, giving the antennæ the appearance of being suddenly enlarged at the tip. In addition, the margins of the head of the confused flour beetle are expanded and notched at the eyes, while the margins of the head of this species are nearly continuous at the eyes. The differences between the two species are clearly shown in figure 46, *e* and *f*.

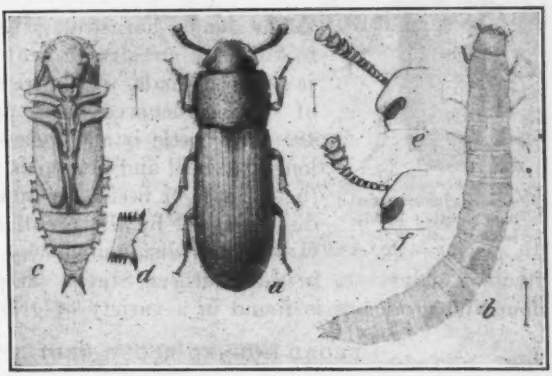

FIG. 46.—The confused flour beetle, the commonest insect recovered from grain shipments. It is about one-sixth of an inch long. *a*, Beetle; *b*, larva; *c*, pupa; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle, showing antenna; *f*, same of the rust-red flour beetle. (Chittenden.)

This insect is similar to the confused flour beetle in feeding and breeding habits, and it is impossible to distinguish between the early stages of the two insects. Although cosmopolitan in distribution, it is found more commonly in the South, where it causes very serious damage to grain products. In addition to the actual damage caused by its feeding activities, serious losses are caused by the nauseous smell and taste that it imparts to the material it infests. Like the confused flour beetle, the rust-red flour beetle is primarily a pest of milled products, and while present in grain shipments it confines its attack in these to grain dust and the surface of broken grains, hence is not a primary pest of commercial shipments.

LONG-HEADED FLOUR BEETLE.[27]

The long-headed flour beetle is a slender, flattened beetle, slightly less than an eighth of an inch long, somewhat similar in form to the

[26] *Tribolium ferrugineum* Fab.

[27] *Latheticus oryzae* Waterh. A closely related species, *Latheticus prosopsis* Chittn., is shown in figure 48.

confused flour beetle but pale yellow and further differentiated by the peculiarly shaped antennæ shown in figure 47 and by the minute canthus behind each eye. It has been reported from most parts of the world infesting wheat, rice, corn, barley, rye, flour, etc. It was first recognized in this country about 13 years ago from specimens taken in Texas. It is not known to be very widely distributed in the United States but is likely to be found in mills and granaries in the South.

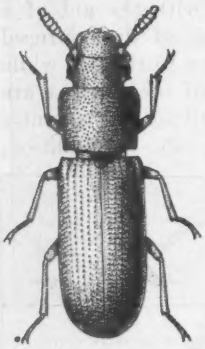

FIG. 47.—Long-headed flour beetle. (Chittenden.)

SLENDER-HORNED FLOUR BEETLE.[28]

The slender-horned flour beetle owes its name to the peculiar structure of the mandibles or jaws of the male, which are armed with a pair of slender incurved horns as shown in figure 49. The beetle is about one-eighth of an inch long, flattened and brownish, closely resembling the other flour beetles in appearance but easily distinguished by the peculiar structure of the jaws. It is distributed over the world and of frequent occurrence in the Southern States. It prefers to feed in flour and meal, but is found in a variety of grains.

BROAD-HORNED FLOUR BEETLE.[29]

The broad-horned flour beetle is closely related to the preceding species and is of similar form and appearance. It may be distinguished from it by the shape of the horns with which the mandibles or jaws of the males are armed. In this species (fig. 50) the horns are broad and stout in contrast to the slender incurved horns of the preceding species. Its habits are similar to those of the slender-horned flour beetle, and it is often found in seaport towns in shipments of grain and grain products.

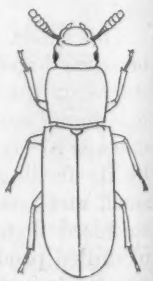

FIG. 48.—*Latheticus prosopis.* (Chittenden.)

SMALL-EYED FLOUR BEETLE.[30]

The small-eyed flour beetle (fig. 51) is the smallest of the so-called flour beetles that infest grain and grain products in this country. It is a tiny, flattened, shiny, reddish-brown beetle, somewhat oblong in form and measuring about one-twelfth of an inch in length. It occurs throughout the world and is widely distributed in this country. It prefers ground products in which to breed, but is not infrequently found in stored grains.

[28] *Gnathocerus maxillosus* Fab. [29] *Gnathocerus cornutus* Fab. [30] *Palorus ratzeburgi* Wism.

A closely related species[31] more common in Europe but occasionally found in this country is very similar in appearance and habits to the small-eyed flour beetle.

TOBACCO BEETLE.[32]

The tobacco beetle is a small, robust, oval, reddish-yellow or brownish red beetle, with head bent down nearly at right angles to the body, giving the beetle a humped appearance when viewed from the side as shown in figure 52. It varies in size, but is usually about one-tenth of an inch long. It is found in all temperate, subtropical, and tropical regions and infests tobacco and many other stored products. It breeds in a variety of seeds and may occasionally be found attacking grains left long in storage in original sacks.

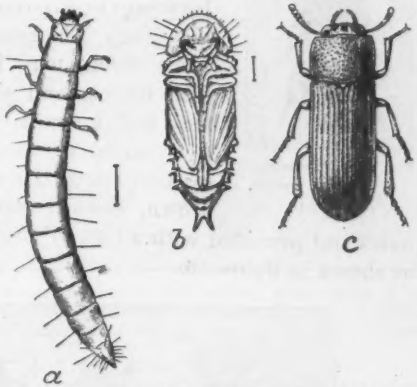

FIG. 49.—The slender-horned flour beetle: *a*, Larva; *b*, pupa; *c*, beetle. (Chittenden.)

DRUG-STORE BEETLE.[33]

The drug-store beetle is very similar in appearance to the tobacco beetle, to which it is closely allied, but differs from it by being more elongate in proportion and in having the wing covers distinctly striated. It is about one-tenth of an inch long. It is cylindrical and uniform light brown; its body is covered with a fine silky pubescence. (See fig. 54.) The larva or grub is very much less hairy than that of the cigarette or tobacco beetle, as a comparison of figures 53 and 55 will show. It is known as the drug-store beetle from its habits of feeding on almost all drugs found in pharmacies. It is a very general feeder, attacking a great variety of stored foods, seeds, and other materials, and has been said to "eat anything except cast iron." It is frequently found in storehouses and granaries in all parts of the world.

FIG. 50.—The broad-horned flour beetle. (Chittenden.)

The eggs of this beetle are laid in almost any dry organic substance. The small white grubs emerging from the eggs tunnel through these substances and when full grown pupate in small cocoons. The entire life cycle may be passed in less than two months.

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[31] *P. depressus* Fab. [32] *Lasioderma serricorne* Fab. [33] *Sitodrepa panicea* L.

FIG. 51.—The small-eyed flour beetle. (Chittenden.)

BLACK CARPET BEETLE.[24]

The black carpet beetle is a small oval beetle between two-sixteenths and three-sixteenths of an inch long. The head and thorax are black, but the wing covers may be either black or dark reddish brown, and clothed with short hairs. Its legs and antennæ are dark yellowish in color. The larva is very characteristic and can be readily recognized. It is reddish or golden brown, clothed with short scale-like appressed hairs and provided with a tuft of long hairs at the end of the body, as shown in figure 56.

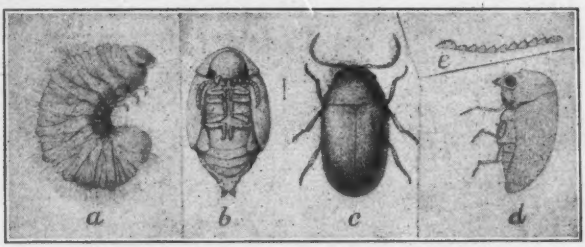

FIG. 52.—The tobacco beetle never attacks grain unless it has been stored for long periods. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden.)

As the name indicates, this insect injures carpets, but in addition it is known to breed in grains and cereals, both whole and ground. The larval stages develop very slowly, and there is but one generation each year. The adults appear in greatest numbers during the spring and early summer. It occurs in Europe and Asia and has been reported from all parts of this country. It is of very common occurrence in houses.

FIG. 53.—The tobacco beetle: Head and leg of larva. (Chittenden.)

LARGER CABINET BEETLE.[25]

The larger cabinet beetle is a small, oval beetle about one-eighth of an inch long, its ground color black mottled with reddish brown, covered with gray and light brown scale-like hairs forming a distinct pattern on the wing covers. The larva somewhat resem-

[24] *Attagenus piceus* Oliv. [25] *Trogoderma tarsale* Melsh.

bles that of the black carpet beetle in appearance. It is about one-eighth of an inch long, reddish brown above and whitish beneath, with body covered with short yellowish brown hairs and with a tuft of short hairs at the tail end. (See fig. 57.) It is well known for its habit of breeding in dead insects and animal substances and is not infrequently found living in grain, flaxseed, castor beans, pumpkin seed, etc. It often becomes a nuisance in laboratories by attacking sample lots of corn, wheat, etc.

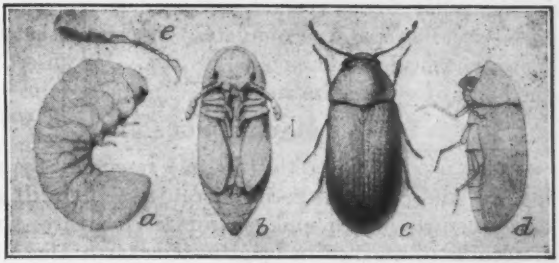

FIG. 54.—The drug-store beetle never attacks grain unless it is stored for long periods unmolested. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden.)

SMALL CABINET BEETLE.[36]

The small cabinet beetle is somewhat similar in appearance to the larger cabinet beetle but smaller and of different color. It varies in length from one-sixteenth to two-sixteenths of an inch, and is black with yellowish white scales that form a broad band across the back and give the body a mottled appearance. The habits of the adult and early stages of this insect are similar to those of the larger cabinet beetle. It is occasionally found in flour mills and granaries, where it infests grain and grain products.

FIG. 55.—The drug-store beetle: Head and leg of larva. (Chittenden.)

MUSEUM BEETLE.[37]

The museum beetle is closely allied to the preceding beetle and resembles it in size and form. Its body is black, covered with yellowish and whitish scales, giving it a spotted appearance. It is a small plump beetle varying in size from one-sixteenth to one-eighth of an inch in length. The larvæ are small active hairy grubs with habits similar to those of the two preceding species. They are occasionally found in grains, both whole and ground, but do not cause noticeable damage.

TWO-BANDED FUNGUS BEETLE.[38]

The two-banded fungus beetle is a handsome little elongate-oval beetle slightly less than an eighth of an inch long. It is red-brown with two broad black bands across the wing covers. Its character-

[36] *Anthrenus verbasci* L. [37] *Anthrenus museorum* L. [38] *Alphitophagus bifasciatus* Say.

istic color pattern is shown in fig. 58. It is distributed over the world and is in general a feeder on fungi and molds, being a scavenger in refuse grain and grain products, decaying vegetable matter, etc. It is frequently found around mills and storehouses where waste material is allowed to accumulate. The larvæ have been bred from moist cornmeal and in spoiled cereals. The insect is often found in the holds of grain ships in wet or damaged grain.

BLACK FUNGUS BEETLE.[39]

The black fungus beetle (fig. 59) resembles the mealworm beetles in form and color but is considerably smaller. It is black or a very dark reddish brown and measures from three-sixteenths to four-sixteenths of an inch in length. The larva (fig. 59, *a*) is yellowish

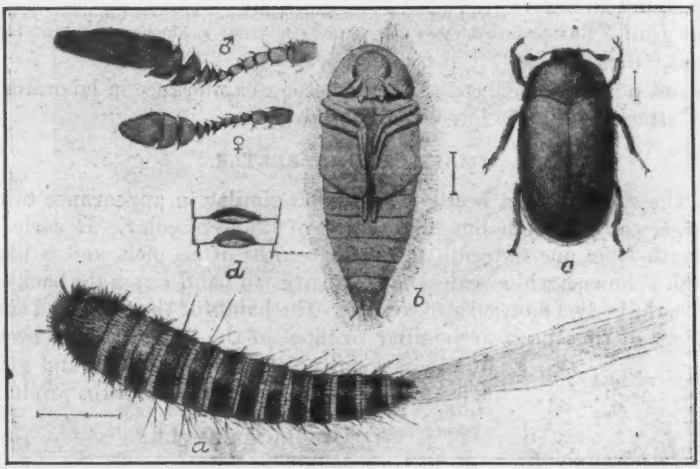

FIG. 56.—The black carpet beetle is chiefly a pest of sample grains, or found in grain dust about elevators or storage bins. *a*, Larva; *b*, pupa; *c*, beetle; *d*, dorsal abdominal segments of pupa; ♂, antenna of male beetle; ♀, antenna of female beetle. (Howard.)

brown and is very similar in form and appearance to young larvæ of the mealworms. This beetle is often found in the same situations as the red-banded fungus beetle. It breeds in damp moldy grain but causes no injury to grain that is sound and dry.

CORN SAP-BEETLE.[40]

The corn sap-beetle may be readily recognized by its peculiar wing covers, which are short and truncate, leaving the tip of the abdomen exposed as shown in figure 60. It is a small dark brown beetle with lighter colored wing covers, oblong-ovoid in shape, and varying in length from one-tenth to one-eighth of an inch. It normally feeds in

[39] *Alphitobius piceus* Oliv. [40] *Carpophilus dimidiatus* Fab.

rotting and decaying fruit and vegetation and in the sap exuding from injured plants. It is quite numerous in cornfields in the South, swarming over the damaged ears and feeding and breeding in the decaying kernels. It is attracted to damp and decaying grain but is seldom found in grain that is clean and dry.[41]

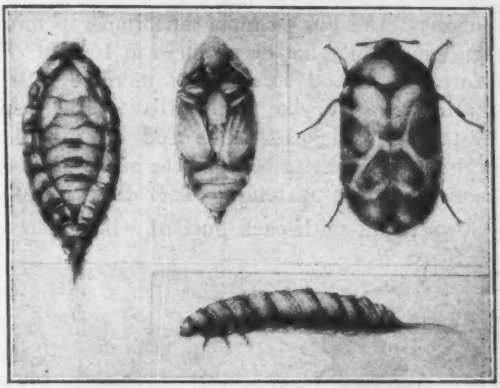

FIG. 57.—The larger cabinet beetle: At left, pupa within larval skin; in center, pupa; at right, beetle; below, well-grown larva.

A closely related beetle[42] that has been introduced from abroad and is becoming more and more abundant is similar in form to the corn sap-beetle, but is slightly larger and is a uniform, shiny, dark brown all over. Its habits are very similar to those of the preceding species.

BOOK-LICE OR PSOCIDS.[43]

Book-lice or psocids are minute, pale, soft-bodied, louse-like insects, about one thirty-second of an inch long, with long, slender antennæ, differing greatly in appearance from other grain-infesting insects. (See fig. 61.) They may be whitish, almost transparent, or quite dark.

FIG. 58.—The two-banded fungus beetle. Adult.

Psocids are of very common occurrence and may be found in nearly any situation. They are almost omnivorous, feeding on any animal or vegetable matter. They are frequently found in grain, but while they have jaws and are capable of feeding upon solid materials, they may be disregarded as pests of grain. They are frequently very abundant in grain and are here recorded because of the curiosity of persons to know what they are. For further information regarding them see Farmers' Bulletin 1104, "Book-Lice or Psocids."

[41] *Carpophilus pallipennis* Say, a purely flower-infesting beetle, has been occasionally reported as infesting stored corn. In these cases large specimens of the corn sap-beetle which closely resemble this species were probably mistaken for it.

[42] *Carpophilus humeralis* Murray.

[43] *Troctes divinatoria* Fab. *et al.*

MITES.[44]

Mites are pale-colored, soft-bodied creatures provided with numerous long hairs, as illustrated in figure 62. They are microscopic in size. As a low estimate the number of mites that may be found on one square inch has been placed at 100,000. They are often found in stored grain and occasionally increase with such rapidity that the grain seems to be fairly alive with them. During heavy infestations their cast skins and dead bodies accumulate in fluffy light brown masses beneath the sacks of grain. If these accumulations are on a warehouse floor they roll up into piles which are blown about with each gust of wind. No other group of pests in

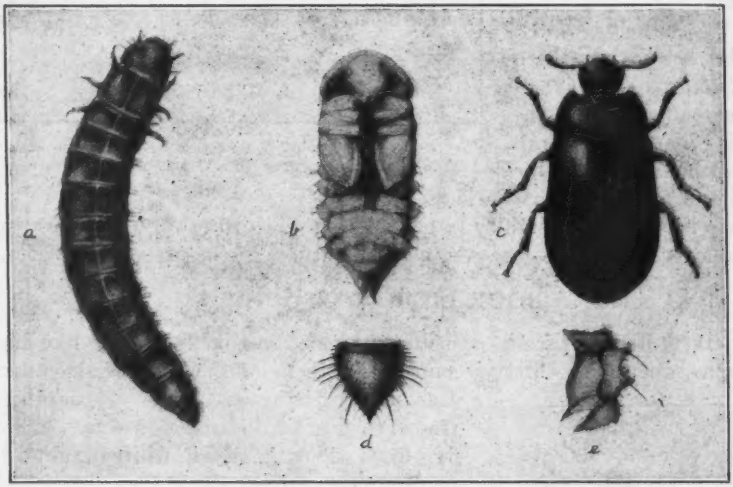

FIG. 59.—The black fungus beetle: *a*, Larva; *b*, pupa; *c*, adult; *d*, caudal segment of larva (Schiödte); *e*, lateral plate of pupa (Schiödte).

grain will produce these masses. When present in large numbers they promote "sweating," impart a disagreeable odor to the grain, and may cause damage by their feeding. Fortunately the mites that attack grain are themselves preyed upon by predacious mites which usually become abundant enough to kill the grain mites in a comparatively short time. If they do not, the screening and fanning of grain will usually reduce mite infestations to a point where no injury takes place.

PARASITES OF GRAIN PESTS.

Grain in bulk is often seen swarming with small black wasplike insects of a size and appearance shown in figure 63. These do

[44] *Tyroglyphus* spp.

not cause injury to grain. On the contrary, they are beneficial, as they are attacking and killing the grain weevils and grain moths. While parasites kill a large number of grain insects, they unfortunately can not be considered of great importance from the standpoint of grain protection, for by the time the grain insects have been controlled by parasites the grain itself has become very badly damaged. For this reason the appearance of a large number of parasites in grain cars or elevators should be disregarded and the grain treated as though parasites were not present.

FIG. 60.—The corn sap-beetle. Adult.

Grain dealers frequently find a small threadlike white worm[45] (fig. 64) about three-quarters of an inch long in grain dust beneath sacks or in the bottoms of bins. This is the larva of a small black fly to be found crawling upon windows of granaries and flour mills. Because of this habit it is called the window-pane fly. Its threadlike larva does no harm to grain but is predacious upon the larvæ of grain pests and clothes moths. It is not abundant enough to be of value in protecting grain.

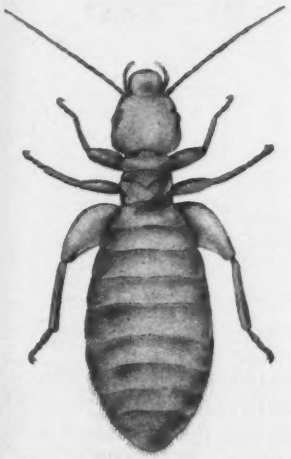

FIG. 61.—Book-louse or psocid.

HOW GRAIN BECOMES INFESTED.

Grain may become infested in a number of ways. It is never possible to settle satisfactorily litigation over responsibility for insect damage to grain without a thorough knowledge of the history of the particular grain shipment involved.

Several of the worst insect pests of grain, notably the Angoumois grain moth and the rice or black weevil, fly to the grain fields from near-by cribs and begin their attack upon the maturing grain. In the case of wheat and similar small grains, the eggs of the insect are laid directly upon the heads of grain. In the case of corn the insects can infest only those kernels that are exposed because of poorly de-

[45] *Scenopinus fenestralis* L.

veloped or damaged shuck covering. In cornfields, especially in the South, where insect infestation occurring in the field is most severe, there are a sufficiently large number of exposed kernels to bring about slight, though widespread, infestation.

It is probably true that in well-grown crops of corn the percentage of kernels infested before the crop is ready for harvest is very small, and throughout the Middle and Northern States is a negligible factor. In the Gulf Coast States, especially in upland fields, the infestation often is very severe. In the case of wheat, grown particularly along the Ohio River, in southern New Jersey, in Pennsylvania,

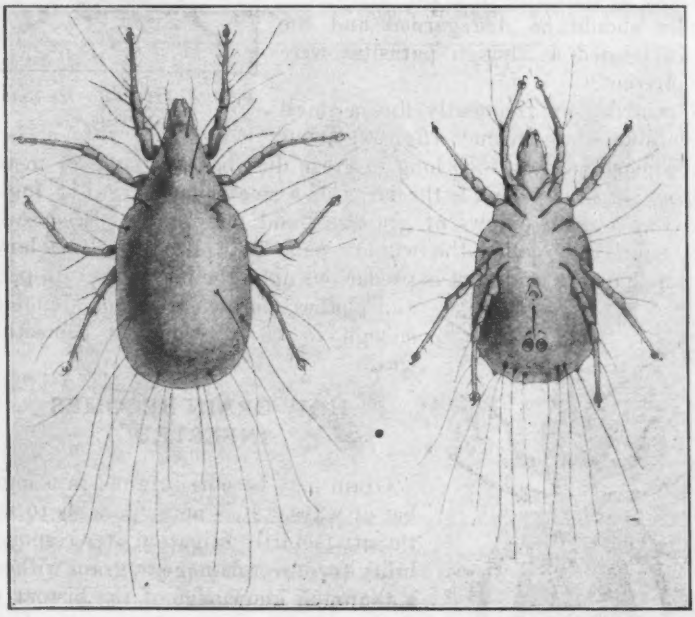

FIG. 62.—Grain mites. (Howard.)

Maryland, Delaware, Virginia, and southward, the field infestation may be much more general than is now believed. Newly thrashed wheat from Maryland arriving in September on the Baltimore market showed infestation ranging up to 6 per cent. While these infestations occurring in the grain before it is harvested are usually unavoidable, they are of great importance as "leaven" which in storage may result in a general infestation of an entire crop, in heating, and in much damage.

After grain has been harvested it is often stored in bins, storehouses, or barns that have held, or still hold, infested grain and which

have not been thoroughly cleaned. Wooden bins and wooden partitions in grain storehouses and in the holds of grain-carrying ships become the nesting places for an incredibly large number of grain pests. Certain of these can and do bore into the softer portions of the partitions and timbers that are used over and over again as dunnage, and the excavations they make serve as hiding places not only for themselves but all other species associated with them. Unless such bins and partitions are thoroughly disinfected by fumigants, these hidden insects can not be killed. The mere spraying of contact insecticides upon the walls will not reach them. If uninfested grain is placed in such bins, it naturally will become infested by the insects coming from the bin walls.

FIG. 63.—Hymenopterous parasite of grain pests. Adult parasite resting upon a kernel of wheat. These tiny gnat-like insects are beneficial but their help usually comes too late to prevent damage to the crop in which they are most abundant.

FIG. 64.—Larva of a kind of fly that preys upon grain beetles and mites. This white threadlike worm is sometimes found in grain dust and attains a length of about three-fourths of an inch; while interesting, it is of no practical value.

Likewise, uninfested grain should not be placed for shipment in sacks previously used for grain storage, for, as shown in figure 32, these old sacks often harbor insects unless they have been treated by heat or fumigation. Certain extensive and costly infestations have been traced directly to the use of secondhand untreated grain sacks.

Grain stored in the open or in poorly constructed cribs or bins may become infested by insects flying in from outside sources.

HOW TO PREVENT PRIMARY INFESTATION.

Infestation of grain in the field can not be entirely prevented, but by proper precautions it can be reduced to a minimum. The first gen-

eration of insects in the maturing grain is usually small, and if the grain is cut as soon as ripe, thrashed as soon as dry, and then placed in storage in clean, deep bins the damage from this source will be very slight. It is when the grain is left in the field long after it is ripe that serious infestation results, for the insects increase in one or two generations to enormous numbers. In the case of corn in the field, only those ears that are damaged or through poor shuck development have kernels exposed are subject to the attack of grain insects. Farmers should therefore grow a variety of corn that develops a long tight shuck.

Newly harvested small grains should not be stored unthrashed for any length of time, as in this condition they are very susceptible to infestation. If promptly thrashed and stored in deep bins, only a thin layer on top of the bin is likely to become infested. Corn may be stored in the shuck if the husk is long and tight and fully covers the tip, but all ears with loose, broken, short, or damaged husks should be shucked and stored separately.

Clean grain should never be stored in old bins, granaries, or storehouses until they have been thoroughly cleaned and freed from the accumulations of waste grain and other materials harboring grain insects. Timbers in bins, granaries, or holds of ships that have become infested with grain insects should be destroyed or treated before being used again. Steel or concrete bins are highly desirable owing to the ease with which they are cleaned.

Bags of all kinds that have previously held grain should not be allowed in granaries or warehouses or be refilled until they have been sterilized by heat or otherwise freed from insects. The use of tight cribs will keep the grain free from infestation by insects that might fly in from the outside.

THE TREATMENT OF INFESTED GRAINS.

Insects infesting stored grain can be destroyed by the use of heat, or by fumigation with poisonous gases. These remedial measures are mentioned only briefly in this bulletin.

HEAT.

A temperature of 120° to 130° F., maintained for a short time, will kill all stages of grain-infesting insects, without injuring the germinating quality of the grain. Owing to the difficulty of subjecting the grain to such a temperature this method of control is used chiefly by millers and large grain dealers who are equipped with commercial driers suitable for the purpose.

FUMIGATION.

Carbon disulphide, carbon tetrachloride, and hydrocyanic-acid gas are the fumigants in most common use to-day for treating infested grain. All things considered, carbon disulphide is the most effective for treating grain in bulk. It is purchased as a liquid, which vaporizes, forming a gas heavier than air. If applied at the top of a gas-tight bin of grain, the gas will penetrate down through the grain, killing the insects without injury to the grain, provided it is dry. Carbon disulphide has one great disadvantage in that its gas is highly inflammable and will explode when mixed with air in certain proportions if fire in any form is brought near it. Notwithstanding this fire hazard, which must always be taken into consideration, carbon disulphide is in general use on farms for the protection of grain in cribs (see U. S. Department of Agriculture, Farmers' Bulletins 799, 1029, and 1483).

Carbon tetrachloride is not so effective as carbon disulphide and fumigation with it costs from two to three times that of fumigation with carbon disulphide, since more of the liquid must be used for the same space. Carbon tetrachloride is not particularly effective at the lower ranges of temperature (60° to 75° F.) suitable for fumigation. Fumigation with this material has, however, the great advantage of removing the fire hazard, as carbon tetrachloride is not inflammable and does not explode in the presence of fire.

Hydrocyanic-acid gas generated from calcium cyanide has been developed during the last two years as an effective fumigant for grain in large elevator bins. The calcium cyanide in a finely divided state is incorporated into the flow of wheat as it enters the bin. Hydrocyanic-acid gas generated from calcium cyanide so distributed throughout the mass of wheat at a given poundage per 100 bushels will, according to the experiments of others, kill all weevils and does not injure the grain for milling purposes. However, grain so treated may carry an odor, and while this odor seems to be of no consequence from the milling and baking standpoint, the grain will be sample graded by Federal inspectors should the odor be detected. This type of fumigation is a highly specialized one, calling for the use of patented equipment.

When grain is stored in sacks in warehouses heavy doses of hydrocyanic-acid gas generated in the general storage space by the pot or barrel method (using from 2 to 2½ pounds of sodium cyanide per 1,000 cubic feet of space) will control grain pests under favorable conditions. This method is discussed in departmental Bulletin 872. It is difficult to get satisfactory kills unless the compartment in which the fumigation is conducted is extremely tight and the sacks are stacked in tiers sufficiently separated so that the gas can reach all sides.

The ethyl acetate-carbon tetrachloride mixture, a fumigant first recommended for the treatment of bulk grain in 1924, is valuable in that no fire hazard appears to be associated with its use. Although it appears that it can be used with safety in elevator bins and elsewhere, the experience with it since 1925 has not been especially favorable, and unless a better grade of chemicals can be obtained commercially so that odors will not be retained by the grain, this fumigant is likely to find a limited field of usefulness. For further information see Department Bulletin 1313 and Farmers' Bulletin 1483.

Chloropicrin, the ethylene dichloride-carbon tetrachloride, and the ethyl monochloroacetate-carbon tetrachloride mixtures are promising nonexplosive and noninflammable fumigants for bulk grain bins to date (October, 1927). Experimental work on a larger scale must be conducted before they can be recommended.

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U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1260

June 1930

Rev. ed. follows

STORED-GRAIN PESTS

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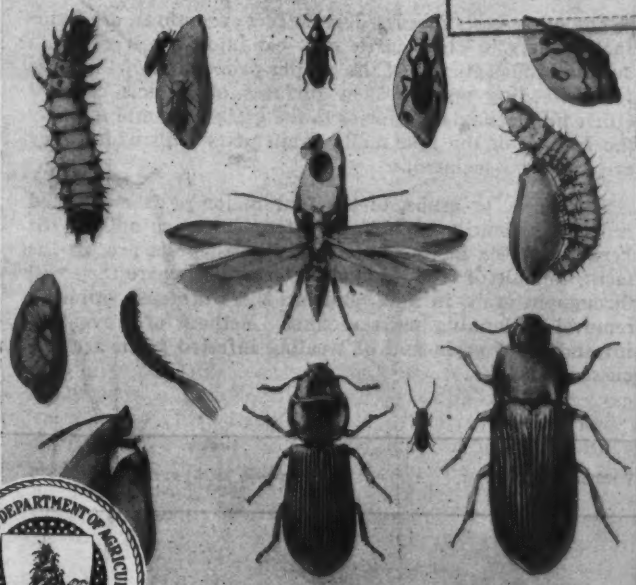

MOST of the damage done by insects to grain in storage and shipments is due to four species. These are the granary weevil, the rice or black weevil, the lesser grain borer or Australian weevil, and the Angoumois grain moth. Others of the 46 species or groups of species described in this bulletin can cause great damage to grain if storage conditions are unusually favorable for their increase. Yet if grain in the unbroken kernel remains unaffected by the four insects mentioned, it is not likely, in commercial storage or shipments, to be sufficiently affected by other insects to cause appreciable loss. These four pests live throughout their larval life entirely within the kernel, where they feed unseen, usually unsuspected, and where they can not be reached by the ordinary methods employed by grain men in their grain-cleaning operations known to the trade as moving, fanning, and screening.

The other pests discussed, with few exceptions, are "surface feeders." Their larvæ may eat into kernels of grain and lie hidden there, yet the greater proportion of them are found feeding upon broken surfaces of kernels exposed either by mechanical injuries to the grain in handling or by the feeding of the four major grain pests with which they are usually associated.

The larvæ, or grubs, of the four major pests mentioned are not ordinarily capable of a free existence outside the kernel, but the larvæ of the other grain pests are, in the main, capable of free locomotion, crawling where they will throughout grain in bulk, and are therefore susceptible to removal by fanning and screening. Methods of preventing infestation of grain and of treating infested grain are discussed briefly.

Washington, D. C. Issued April, 1922; revised June, 1930

STORED-GRAIN PESTS

By E. A. Back, *Principal Entomologist in Charge*, and R. T. Cotton, *Senior Entomologist, Division of Stored-Product Insects, Bureau of Entomology*

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POPULAR CLASSIFICATION OF GRAIN PESTS

SINCE THE ESTABLISHMENT of the Federal standards for grain under the provisions of the grain standards act, Federal grain supervisors and federally licensed grain inspectors are required to identify the various species of "live weevils and other insects injurious to stored grain" which may be present in the grain, and uniform names for grain insects should be used. Such uniform terminology will indicate definitely to all interested persons, including shipper, purchaser, and elevator operator, the exact nature of the insect found. Of the four major pests, the granary weevil, the rice or black weevil, and the lesser grain borer may be well called "grain weevils." The fourth of the major pests, the Angoumois grain moth, so destructive to wheat and corn, may be called "grain moth." Other insects likely to be found in any lot of grain may be called simply "beetles," "moths," and "meal worms," for their pres-

ence usually does not indicate a condition likely to affect the trade, provided that after the grain has reached the elevator it is screened and fanned to remove these insects.

The writers have divided the insects discussed in this bulletin into grain weevils, grain borers, grain moths, flour moths, meal worms, grain and flour beetles, psocids, and mites. In some respects this is not a satisfactory grouping, especially for the insects listed as "grain and flour beetles," but it has the advantage of definitely placing the most serious insects troublesome in bulk grain.

GRAIN WEEVILS

Of the four true weevils that attack grain in the United States only two are of primary importance at present, the granary weevil and the rice or black weevil. The broad-nosed grain weevil and the coffee-

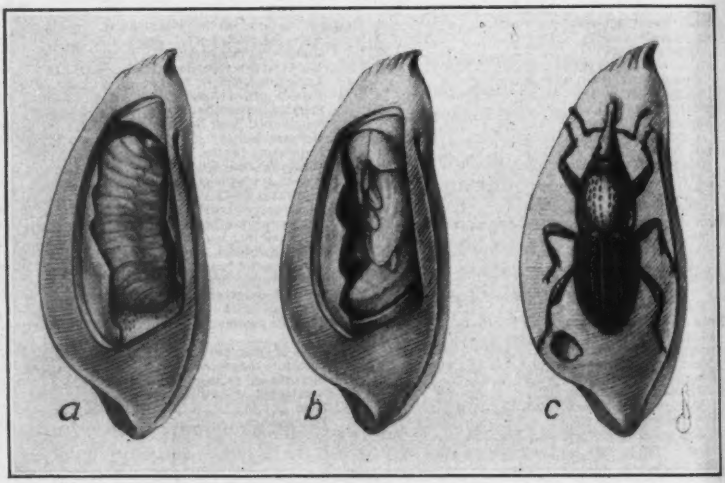

FIGURE 1.—Life stages of the granary weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult. Note hole in kernel made by the adult in order to leave the seed and hole that it is eating into the kernel for the purpose of laying eggs. This weevil closely resembles the rice weevil, but has no papery wings beneath its wing covers and the dotlike punctures on the back behind its head are elongate rather than round

bean weevil are of minor importance except locally. These four weevils have an elongated beak or snout, as shown in the illustrations, though the beak of the coffee-bean weevil is greatly reduced.

GRANARY WEEVIL

The granary weevil, *Sitophilus granarius* L. (fig. 1), is a small, moderately polished, chestnut-brown or blackish beetle with head prolonged into a long slender snout at the end of which are a pair of stout mandibles or jaws. It is not more than three-sixteenths of an inch long, and often smaller. It has no wings under its wing covers and the thorax is well marked with longitudinal punctures,

two characteristics that distinguish it from the closely related rice weevil, with which it is often found associated. The well-grown footless, whitish grub or larva and the pupa are shown at *a* and *b*, respectively, in Figure 1. The granary weevil is one of the oldest known insect pests, is a universal feeder upon grains, and is cosmopolitan, having been carried by commerce to all parts of the world. It prefers a temperate climate and is more frequently found in the Northern States than in the South.

Both adults and larvæ feed voraciously on a great variety of grains. The adult weevils live, on an average, from seven to eight months, the females laying from 50 to 250 eggs each during this period. Before laying her eggs the female bores a small hole in the grain berry with her mandibles. When this has been made she turns about and lays in it an egg which she then covers with a gelatinous fluid that seals the hole. The small, white, fleshy and legless grubs that hatch from the eggs burrow about inside the kernels. When fully grown these transform to the pupal stage and then into the adult weevil form.

In warm weather the granary weevil requires about four weeks to complete its development from the egg to the adult weevil. The developmental period is greatly prolonged by cold weather.

RICE OR BLACK WEEVIL

The rice or black weevil, *Sitophilus oryza* L., is a small snout-beetle which varies considerably in size but rarely measures more than one-eighth of an inch in length. (Figs. 2 and 3.) It varies in color from reddish brown to nearly black and is usually marked on the back with four light reddish or yellowish spots. It closely resembles the granary weevil in form, but it has well-developed wings beneath its wing covers, differs in color and markings, and has the thorax densely pitted with round, instead of longitudinal punctures. Figure 2 gives a good impression of the appearance of the rice weevil and its earlier stages.

This weevil has been known from early times. It is found in all parts of the world where grain is used and is one of the very worst pests in stored grain. It is particularly abundant in warm countries, where it breeds continuously and rapidly destroys all unprotected grain. Throughout the South it causes tremendous losses to corn (figs. 4, 5, 6, and 7) and is the commonest of the serious pests of commercial grain shipments.

The adult weevil lives, on an average, four or five months, each female laying between 300 and 400 eggs during this period. The early stages are almost identical in habit and appearance with those of the granary weevil and need not be further described. The rice weevil is a strong flier. The adults fly from granaries to the fields of grain and there start the infestation that often proves so disastrous after the grain has been harvested. During summer weather the egg, larva, and pupa stages may be passed in as few as 26 days. This period, of course, is greatly prolonged during cool or cold weather. For a further discussion of this pest see Farmers' Bulletin 1029, United States Department of Agriculture.

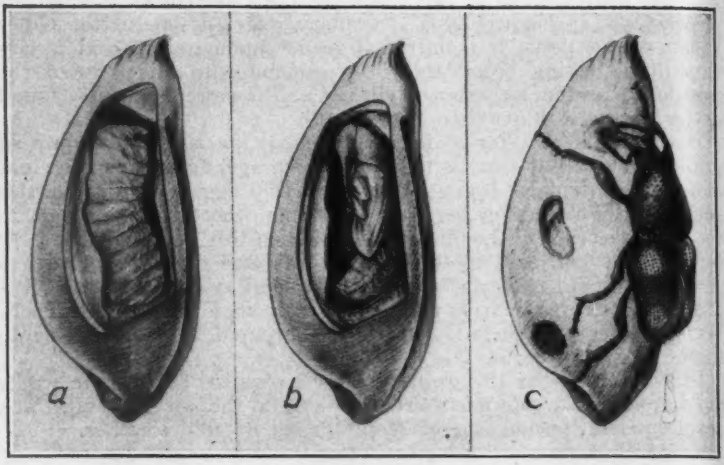

FIGURE 2.—Life stages of the rice or black weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult feeding upon kernel. Note in *c* the hole in lower portion of kernel made by the adult on leaving the seed and at two points higher up shallow holes made by the adult in feeding upon the seed after emergence. The adult weevil is at once distinguished from the granary weevil, shown in Figure 1, by the four light reddish brown or yellow spots on its wing covers, by the possession of wings beneath the wing covers, and by the many rounded punctures on the back behind its head

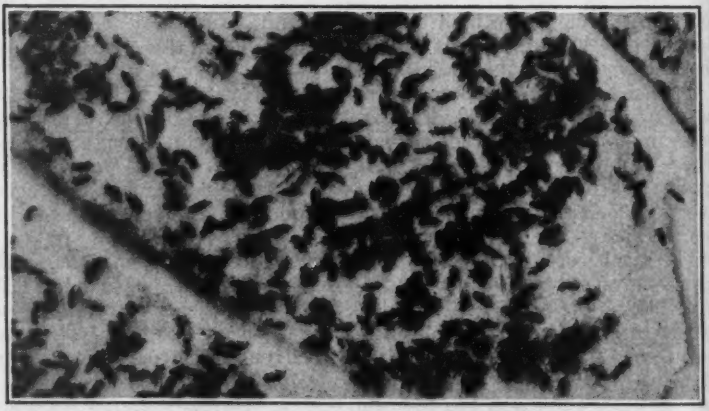

FIGURE 3.—The rice or black weevil: Many adult weevils caught in the mesh of a cloth sack containing pearled barley. Compare their size with that of the barley kernels. Adult weevils when disturbed usually "play possum," but if spread upon a cloth in the sun the live ones will soon show signs of life

FIGURE 4.—Ear of corn with a poor, loose shuck. It is badly infested with rice or black weevils. As the adult weevils feed, they push from the kernels the chewed-up portions, frass, etc., and this material, resembling white dust, collects in large quantities between the kernels and the shuck, or, if the ears are shucked, it falls like powder onto any object below the ear. (Back)

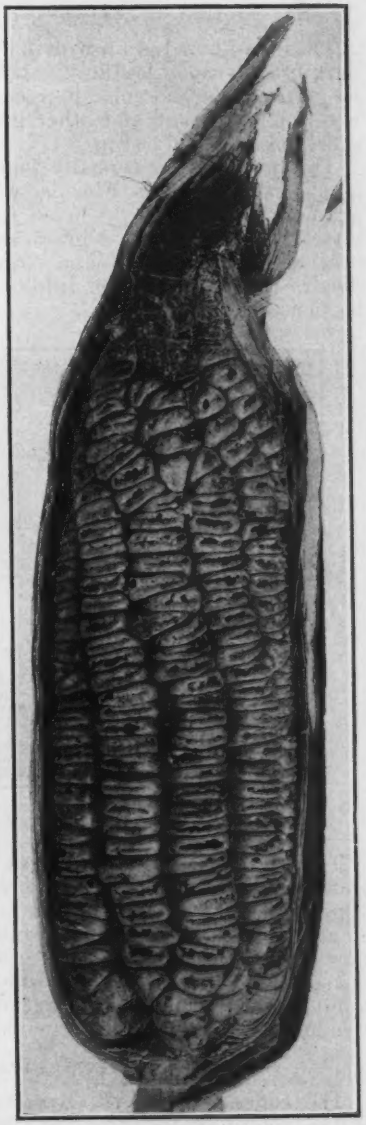

FIGURE 5.—An ear of corn badly damaged by rice or black weevils. This ear has been hit against a table to jar loose the powdery substance, sometimes called the farinaceous material, and so reveals the great damage done by the weevils. The kernels of the ear have been reduced to powder and shell. (Back)

BROAD-NOSED GRAIN WEEVIL

The broad-nosed grain weevil, *Caulophilus latinasus* Say, is a small dark-brown snout beetle slightly less than one-eighth of an inch long. In form and color it resembles the granary weevil somewhat but differs from it and other grain-infesting weevils by having a short, broad snout. (Fig. 8.)

This weevil is occasionally found in Georgia and South Carolina and is widespread in Florida, where it is a serious pest of stored grains. It is unable to breed in dry, hard, uninjured grain, but attacks soft or damaged grain, or grain that has been attacked by other grain insects. It is a strong flier, and, like the rice weevil, flies to the cornfields and infests the grain before it becomes fully hardened.

FIGURE 6.—Kernels of corn taken from badly infested ear corn, showing how the rice or black weevils can thoroughly destroy all parts of the kernel. (Back)

The adult weevils normally live for about five months, and during this time the females lay between 200 and 300 eggs. The small white eggs are usually laid in broken portions of the grain. They hatch in a few days, and the small, white, legless grubs feed on the softer portions of the grain until they become fully grown. They then change to a white pupal form which in a few days transforms to the adult beetle and cuts its way out of the grain. The period from egg to adult in summer is about one month.

COFFEE-BEAN WEEVIL

The coffee-bean weevil, *Araecerus fasciculatus* DeG., is a very active, robust beetle from two-sixteenths to three-sixteenths of an inch long, dark brown in color, clothed with a mottled light and dark-brown pubescence. It may be easily recognized from Figure 9.

This weevil is found in many countries and is extremely abundant in the Southern States, where it breeds in dried fruit, coffee

berries, cornstalks, corn, and the seed and seed pods of an almost endless variety of plants. It is a strong flier and is frequently to be seen in the cornfields of the South on the exposed and damaged ears. It lays its eggs in the soft kernels of corn, and breeding continues after the corn has been harvested and placed in storage. It does not cause much damage to corn in storage, as the corn becomes too hard to be attractive. It may, however, be very abundant locally in corn in Florida during the first three months of storage, and has been reported as completely destroying a sack of kafir seeds in Honolulu. Taking the country at large, the coffee-bean weevil is a very minor grain pest. Figure 10, *a* and *b*, shows the rather characteristic holes cut in the kernels of corn and in corn shucks by the larvæ and emerging adults.

FIGURE 7.—Slip-shuck corn showing holes eaten through the shuck by the rice or black weevil. These holes make passages through which all kinds of grain pests move back and forth to bring about a more speedy destruction of the kernels. (Back)

GRAIN BORERS

Two species of grain borers are now established in the Southern States. The lesser grain borer bids fair to become a very serious pest of grain throughout the South. The larger grain borer has not yet become a factor in commercial shipments of grain.

LESSER GRAIN BORER

The lesser grain borer, *Rhizopertha dominica* Fab., known to many grain dealers more popularly as the "Australian wheat weevil," because of the large supplies of wheat infested by it that reached this country from Australia during the war, is one of the smallest beetles injurious to grain in this country. It is widespread in the Gulf States, and grain samples infested with this beetle are to be found in many large grain centers. It is readily distinguished from other grain pests by its slender cylindrical form and small size. It is

polished dark brown or black in color, with a somewhat roughened surface, about one-eighth of an inch long and one thirty-second of an inch wide. Its head is large, prominent, and bent down under the thorax. The larva, pupa, and adult stages are illustrated in

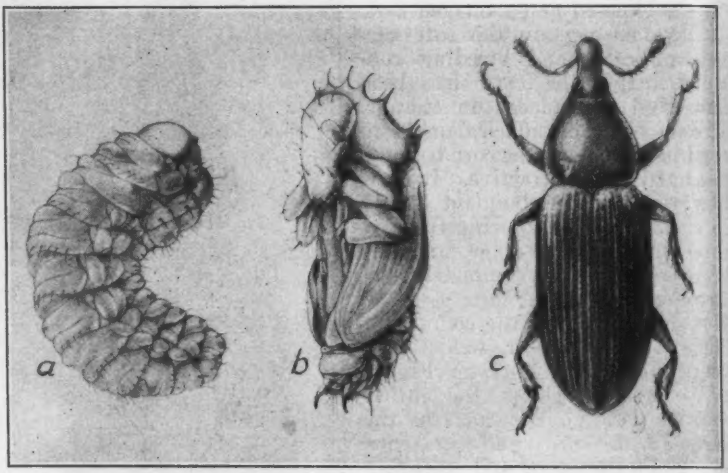

FIGURE 8.—The broad-nosed grain weevil: *a*, Full-grown larva; *b*, pupa; *c*, adult weevil. This weevil is not found in northern-grown grains. It is now present in the southeastern Gulf States. The adult weevil is slightly less than one-eighth of an inch long. It is distinguished from the rice and granary weevils by its much shorter beak

Figure 11. It belongs to a family (Bostrychidae) of beetles that have the head turned down under the thorax and are armed with powerful jaws with which they can cut directly into wood. Originally native to the Tropics the lesser grain borer has spread through commerce to all parts of the world.

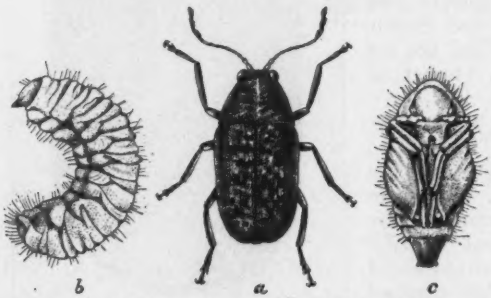

FIGURE 9.—The coffee-bean weevil: *a*, Adult; *b*, well-grown larva; *c*, pupa. The adult is about three-sixteenths of an inch long, of a dark brown color covered with a light and dark brown hairiness. (Chittenden)

Both beetles and larvæ cause serious damage in warm climates, attacking a great variety of grains. The destruction of which they are capable is shown by the wheat kernels of Figure 12, which are literally riddled by the boring adults and their young. The females lay from 300 to 500 eggs each, dropping them singly or in clusters in the loose grain. The eggs hatch in a few days and the small whitish grubs crawl actively about the grain, feeding on the flour produced by the boring

of the beetles, or boring directly into grains that have been slightly damaged. They complete their growth within the grain, transform to white pupæ, and in time change to adult beetles which cut their way out of the grain. The period from egg to adult in summer is said to be about a month.

FIGURE 10.—Work of the coffee-bean weevil; *a*, Holes made in corn shucks by the adult weevils eating their way out from the kernels beneath; *b*, two kernels in which larvæ of this insect have developed. Note that a single larva devours a large portion of a single kernel, which is not true of the rice weevil

LARGER GRAIN BORER

The larger grain borer, *Dinoderus truncatus* Horn, is a small, dark brown, elongate-cylindrical beetle about one-sixth of an inch long. As may be seen in Figure 13, it is very similar in appearance to the lesser grain borer, but may be distinguished by its larger size and comparatively smooth, polished surface.

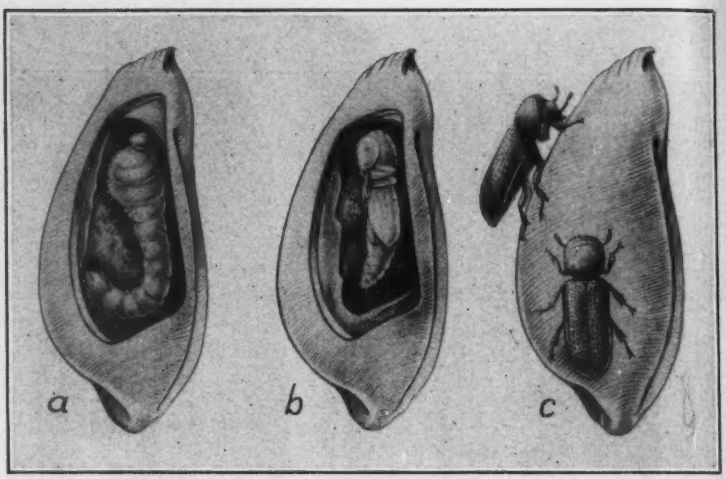

FIGURE 11.—The lesser grain borer in wheat kernels: *a*, The well-grown larva; *b*, the pupa; *c*, two adult weevils. Adult borer is shiny roughened dark brown or black, about one-eighth of an inch long

FIGURE 12.—Kernels of wheat thoroughly riddled and devoured by the boring and feeding of the lesser grain borer and its larva. Such damaged kernels are always surrounded by much powder or flourlike material which the insects have chewed up and pushed out from the kernels

This beetle is a tropical insect not as yet widely distributed in this country. It is occasionally found infesting corn (fig. 14) in the Southern States. Its habits are similar to those of the lesser grain borer. It also has probably acquired its grain-feeding habits rather recently.

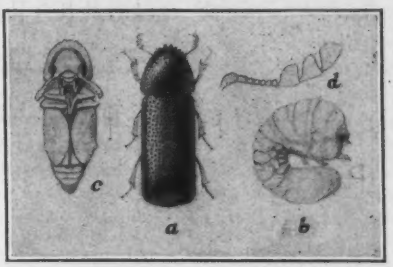

FIGURE 13.—The larger grain borer: a, Adult insect; b, larva; c, pupa; d, antenna of adult. Adult borer is shiny polished dark brown, about one-sixth of an inch long. a, b, c, About six times natural size; d, highly magnified. (Chittenden)

GRAIN MOTHS

The grain moths include only those moths capable of destroying sound, unbroken grain kernels. They are not so abundant as the flour moths, which are principally pests in broken, damaged kernels or milled products.

ANGOUMOIS GRAIN MOTH

The Angoumois grain moth, *Sitotroga cerealella* Oliv., is a small buff or yellowish-brown moth with a wing expanse of about one-half inch. This is the moth most commonly found in infested grain in this country and is not likely to be confused with any other. It attacks all cereal grains, is found in all parts of the world, and is particularly injurious in the South, where it attacks grain both in the field and in storage.

FIGURE 14.—Kernel of corn showing work of adult of larger grain borer. The adult borers tunnel in all directions and reduce kernels to powder and shells. Enlarged. (Chittenden)

Each female moth may lay as many as 400 eggs, which are white when first laid but soon change to a reddish color. The eggs are laid on or near the grain. Upon hatching, the minute white larva or caterpillar bores into a kernel of grain and begins feeding on the contents. When full grown it eats out a channel to the outside of the seed but leaves a thin layer of the seed coat intact. It then changes to a reddish-brown pupa, and later the adult or moth emerges, pushing aside the thin section of seed coat that covers the exit from the channel. The development from egg to adult may be completed in five weeks. Figures 15 and 16 show the successive stages in the development of this insect in a kernel of wheat and of corn from the time the egg is laid until the adult appears. In Figure 17 is shown an ear of corn with the external evidence of heavy attack, and in Figure 18 are shown wheat kernels with the emergence holes of the moth. For a further discussion of this pest see Farmers' Bulletin 1156, The Angoumois Grain Moth.

WOLF MOTH

The wolf moth, *Tinea granella* L., is a small moth about the size of the Angoumois grain moth, creamy white and thickly mottled with brown. The mottled appearance distinguishes it from the Angoumois grain moth. It infests all kinds of grain, both in the

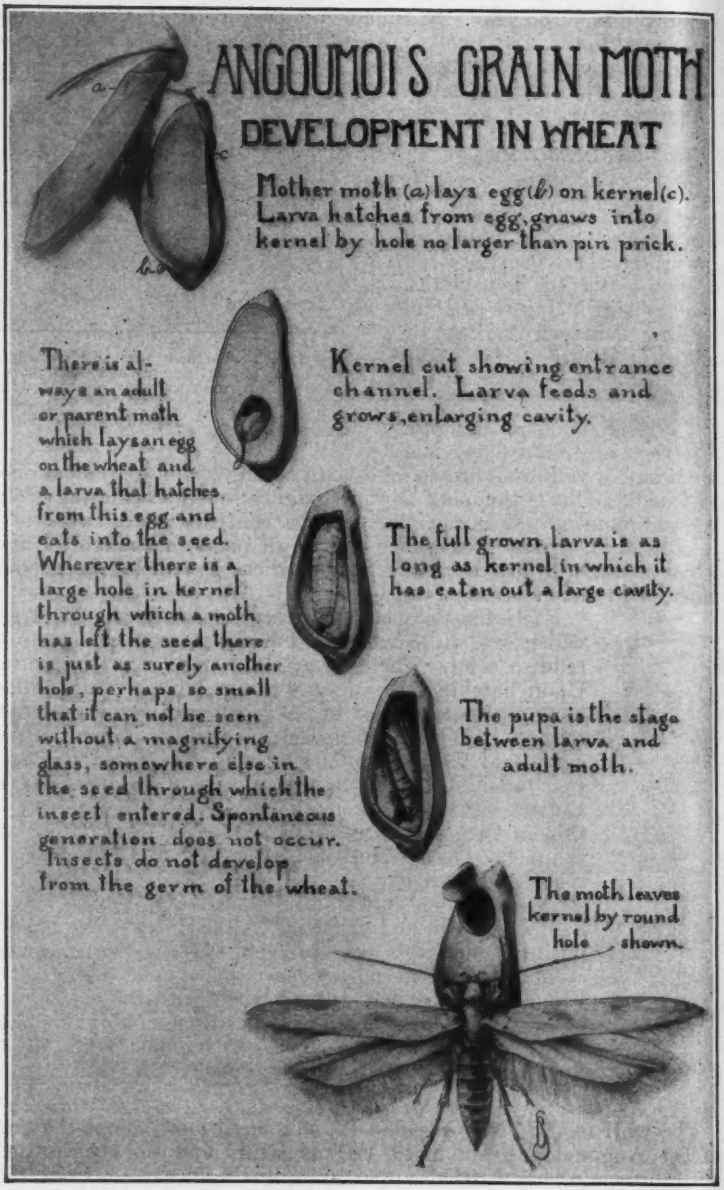
ANGOUMOIS GRAIN MOTH
DEVELOPMENT IN WHEAT
Mother moth (a) lays egg (b) on kernel (c). Larva hatches from egg, gnaws into kernel by hole no larger than pin prick.
Kernel cut showing entrance channel. Larva feeds and grows, enlarging cavity.
The full grown larva is as long as kernel in which it has eaten out a large cavity.
The pupa is the stage between larva and adult moth.
The moth leaves kernel by round hole shown.
There is always an adult or parent moth which lays an egg on the wheat and a larva that hatches from this egg and eats into the seed. Wherever there is a large hole in kernel through which a moth has left the seed there is just as surely another hole, perhaps so small that it can not be seen without a magnifying glass, somewhere else in the seed through which the insect entered. Spontaneous generation does not occur. Insects do not develop from the germ of the wheat.

FIGURE 15.—Life cycle of Angoumois grain moth on wheat. (Back)

field and in storage. The larva feeds on the grain and webs the kernels together.

The wolf moth is distributed throughout the Northern States but is not very abundant and can not be compared with the Angoumois grain moth for destructiveness.

PINK CORN WORM

The pink corn worm, *Pyroderces rileyi* Wals., is the larva or caterpillar of a small moth. (Fig. 19.) It is about five-sixteenths of an inch long when full grown; pink in color, with head and thoracic shield pale brown. Figure 20 gives a good idea of its appearance. The moth which develops from this worm or larva is smaller than the Angoumois grain moth, with a wing expanse of slightly less than half an inch. The forewings are banded and mottled with yellow,

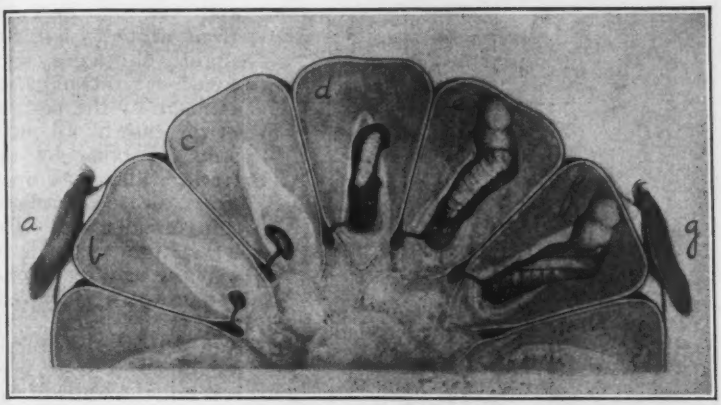

FIGURE 16.—Cross section of ear of corn showing development of Angoumois grain moth in corn. The newly hatched larva crawls down to the germ end of the corn and begins feeding upon the soft germ. As it grows older and stronger it eats out into the firmer portion of the kernel and finally, in most instances, eats to the outer end. (Back)

reddish brown, and black, as shown by Figure 19. The pale grayish hindwings are very slender and are edged with long fringes. The pupa is shown in Figure 21.

This insect is common in the South, where it causes considerable injury to corn, both in the field and in storage. Infestation begins in the field and is continued after the corn is placed in storage. The very characteristic injury is shown in Figures 22 and 23. The large amount of frass that is loosely webbed together and fills the interstices between the kernels or is crowded into the cavities of kernels that have been eaten out is a reliable indication of the presence of this pest. The pearly white eggs are laid singly or occasionally in twos or threes. The pinkish larvæ feed on the seed, husk, and cob with equal relish. Though capable of serious injury to corn, in particular as it comes to maturity in the field, and while in the cribs on southern farms, the pink corn worm is seldom a serious pest of commercial shipments.

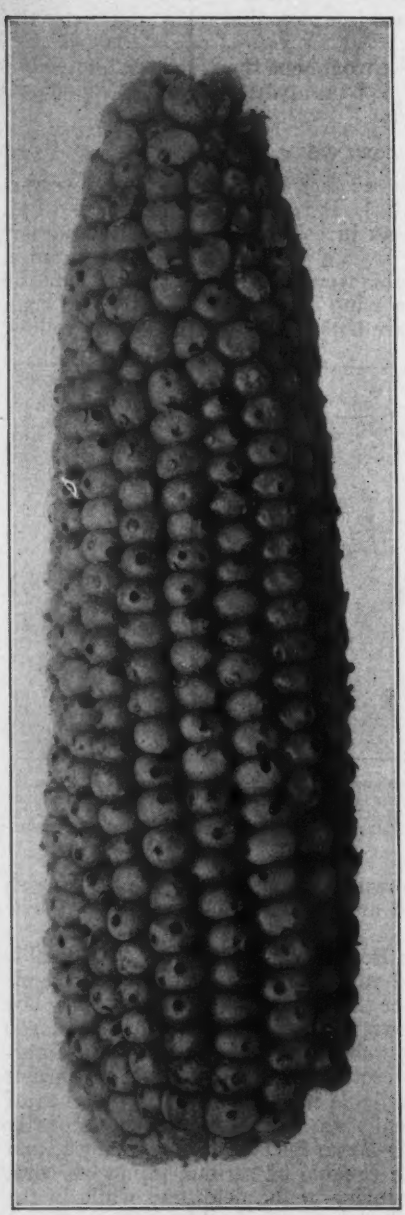

FIGURE 17.—Ear of pop corn showing heavy infestation by the Angoumois grain moth. Note that certain of the kernels have three emergence holes, and that many have served as food for two larvæ. The development of a single insect in a kernel causes a loss of from 13 to 24 per cent in weight

RICE MOTHS

The rice moth, *Corcyra cephalonica* Staint., has a wing expanse of about half an inch and is of a pale grayish-brown or tawny color. Its characteristic appearance is shown in Figure 24. The larva (fig. 25) resembles somewhat that of the Indian meal moth, being when full grown about half an inch long and varying in color from white to a dirty, slightly bluish gray with occasional tints of green. Damage by the pest, as in the case of all moth pests, is done by the larvæ, which feed upon rice, cocoa, chocolate, ship biscuits, etc. The larvæ produce a dense webbing as they become well grown. When feeding upon grains they spin dense silken tubes, webbing the grain kernels into the walls of the tubes. The pupa is shown in Figure 26. The rice moth is seldom found in this country and has not become very widely disseminated.

FLOUR MOTHS

Among the flour moths are some of the commonest and most serious pests of grain products. They are designated as flour moths not because they feed entirely upon flour or milled products, but because they seldom attack sound grain kernels. They prefer broken grains, grains injured by major grain pests, and more especially cereal milled products such as flour, breakfast foods, meals, etc. All three

of the flour moths are commonly found in grain warehouses, but the Indian meal moth and the meal snout moth are probably the most

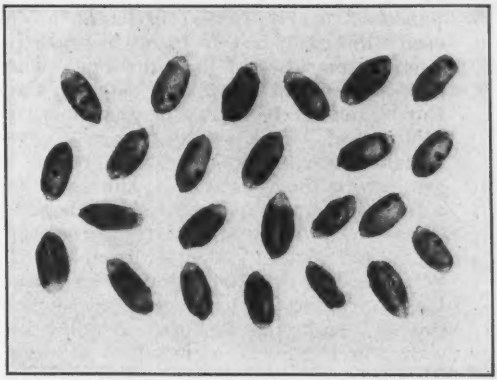

FIGURE 18.—Kernels of wheat showing the small round emergence holes that prove that the Angoumois grain moth has developed in the seed, thus reducing the weight somewhat over 50 per cent. (Back)

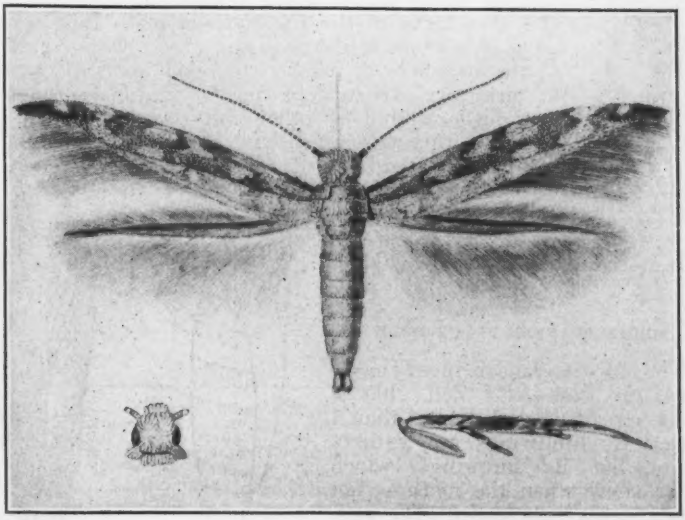

FIGURE 19.—The pink corn worm: Moth, much enlarged; head and leg more enlarged. The moth has a wing spread of a little less than half an inch. (Chittenden)

frequently reported. These two moths may, under specially favorable conditions, become established in whole grain and other seeds and cause injury especially by eating out the germ.

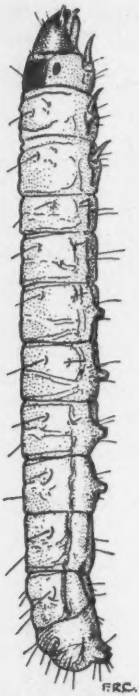

FIGURE 20.—The pink corn worm: Full-grown larva, side view, greatly enlarged. When full grown the larva is pink and about five-sixteenths of an inch long. (Chittenden.)

INDIAN MEAL MOTH

The Indian meal moth, *Plodia interpunctella* Hbn., is a rather handsome moth with a wing expanse of nearly three-fourths of an inch. It is easily distinguished from other grain pests by the peculiar marking of its forewings. These are reddish brown with a coppery luster on the outer two-thirds, but whitish gray on the inner or body end. Moths and larvæ are shown in Figure 27. The female moths lay from 300 to 400 eggs, singly or in groups, on food material. The eggs hatch within a few days into small whitish larvæ or caterpillars. These larvæ feed upon grains, grain products, dried fruits, nuts, and a rather wide variety of foodstuffs. When full grown, the larvæ are about half an inch long, dirty white in color, varying sometimes to greenish and pinkish hues. A full-grown larva is shown in Figure 28, clinging to a kernel of wheat. This larva spins a silken cocoon and transforms to a light-brown pupa, from which the parent moth later emerges. The Indian meal moth may pass through its egg, larva, and pupa stages in about four weeks during warm weather.

The larva of the Indian meal moth spins a web as it becomes full grown, and leaves behind a silken thread wherever it crawls. When sacks of cracked corn, meal, or corn in the ear that has been previously injured by other pests become heavily infested, this webbing often is sufficiently abundant to attract attention. The loosely clinging web shown on the ear of corn in Figure 29 is characteristic of this pest.

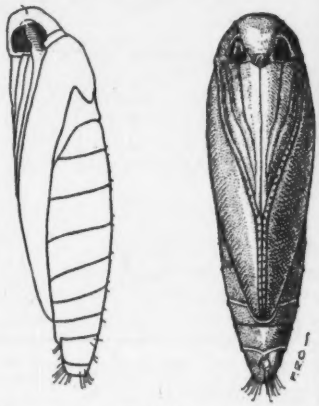

FIGURE 21.—The pink corn worm: Pupa, ventral view at right, lateral view at left. Enlarged. (Chittenden)

MEDITERRANEAN FLOUR MOTH

The Mediterranean flour moth, *Ephestia kuehniella* Zell., has a wing spread of slightly less than 1 inch. Its hindwings are a dirty white, but its forewings, which alone show when the moth is not flying, are a pale leaden gray with transverse wavy black markings. (Fig. 30.)

The Mediterranean flour moth is a native of Europe. Its first discovery in the United States was in

California in 1892. Since then it has spread to practically all the States and is recognized as the most serious pest of flour mills, owing to the silken threads which the larvæ spin wherever they crawl. These webs mat the flour or meal together and eventually clog machinery so that mills have to shut down for a thorough cleaning and treatment. Although preferring flour and meal, the Mediterranean flour moth attacks grain, bran, and cereal products and is commonly found in storehouses and granaries.

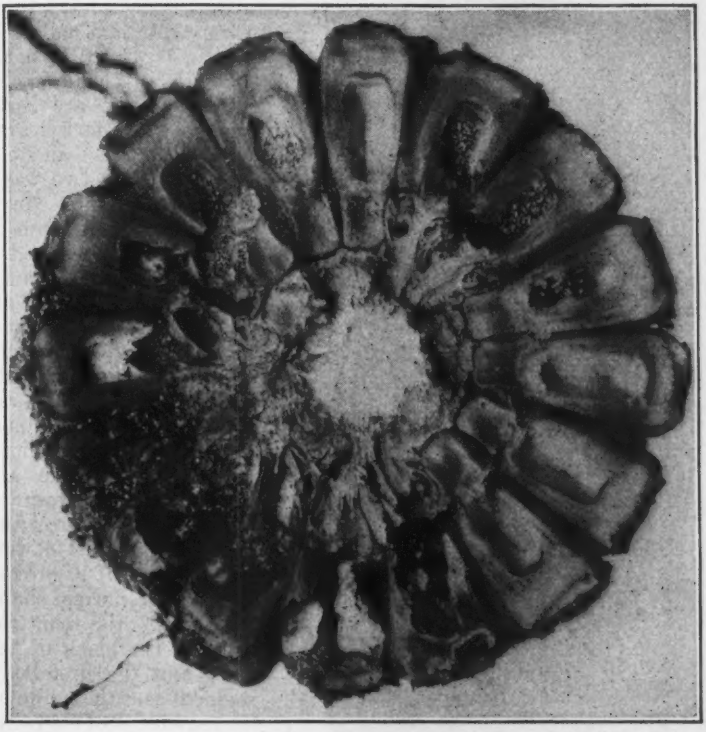

FIGURE 22.—Ear of corn cut to show characteristic feeding and destruction by pink corn-worm larvæ. Note that the larvæ eat from one kernel to another, often severing the kernels from the cob. The larvæ sometimes eat into the cob, and there transform to the pupa stage. The pupæ are about one-third as long as the kernels shown

The female moth lays small white eggs in accumulations of flour, meal, or waste grain. From the eggs the small larvæ hatch in a few days. When full grown, these are about half an inch long and are of a whitish or pinkish color with a few small black spots on the body. The full-grown larva spins a silken cocoon in which the insect transforms to a reddish-brown pupa. Later the parent moth emerges from the pupa. During warm weather, the Mediterranean flour moth requires about nine weeks to pass through its egg, larva, and pupa stages.

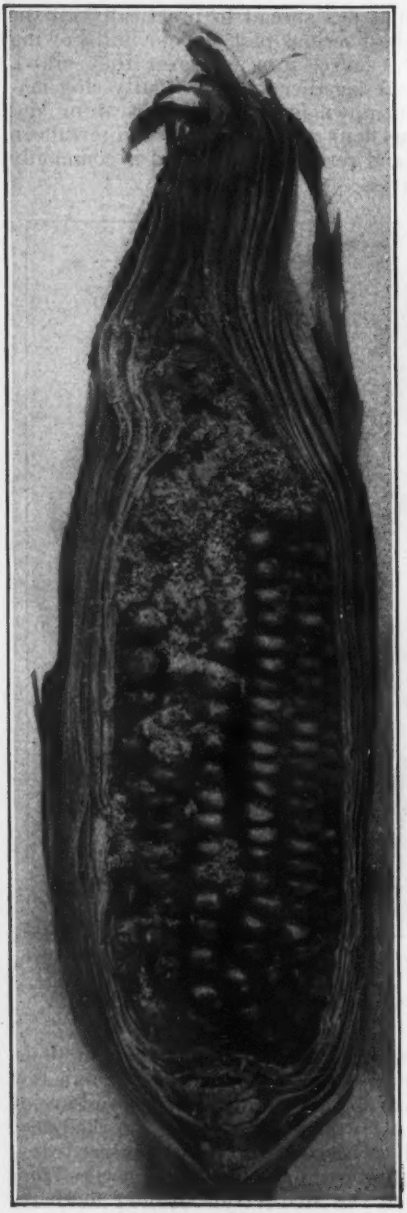

FIGURE 23.—Ear of corn with portion of shuck removed to show surface feeding by larvæ of the pink corn worm. Often many kernels drop from the ear when the shucks are removed because of the feeding of the pink corn worm larvæ

MEAL SNOUT MOTH

The meal snout moth *Pyralis farinalis* L., is brownish in color, somewhat larger than the Indian meal moth, though varying in size, usually having a wing spread of about 1 inch. Its forewings are marked in a characteristic pattern indicated in Figures 31 and 32; they are light brown with dark-brown patches at base and tip and each with two wavy transverse white lines. The meal snout moth is widely distributed and a general feeder in the larva stage upon cereals of all kinds, both ground and in the berry. It sometimes attracts much attention because of its capacity to web up and bind together seeds of various kinds. The larvæ are whitish and attain a length when full grown of about 1 inch. The two larger larvæ of Figure 31 indicate the normal shape and show the contrast between the black of the head and the first body segment and the white of the remainder of the body. Often the body of the larva is tinged with orange toward each end. The larvæ spin peculiar tubes of silk and particles of the food material. They rest in these tubes, which are very tough, and feed from the openings at the ends. When full grown the larvæ

leave the tubes, spin silken cocoons, often covered with food particles, and transform to the pupæ from which later emerge the adult moths. The meal snout moth may require only eight weeks to pass through the egg, larva, and pupa stages.

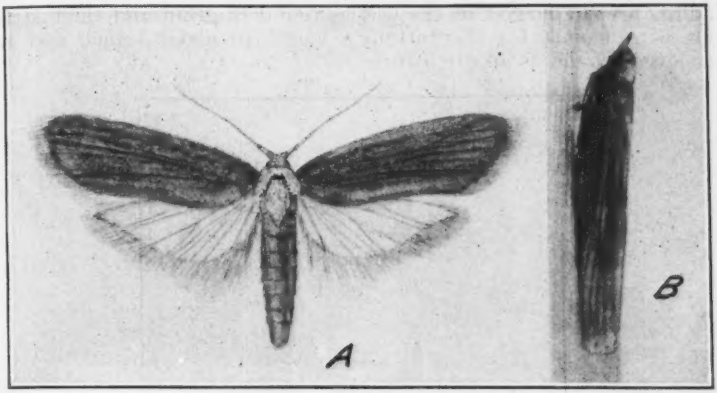

FIGURE 24.—The rice moth: *a*, Mature moth, dorsal view, with wings spread; *b*, side view of same moth with wings folded about body. The moth is of a grayish brown of tawny color, with a wing spread of about half an inch. Much enlarged. (Chittenden)

The meal snout moth is primarily a pest of seeds that are held for some time in cool and damp localities. Outbreaks that have come to the attention of the writers have always been centered in grain that

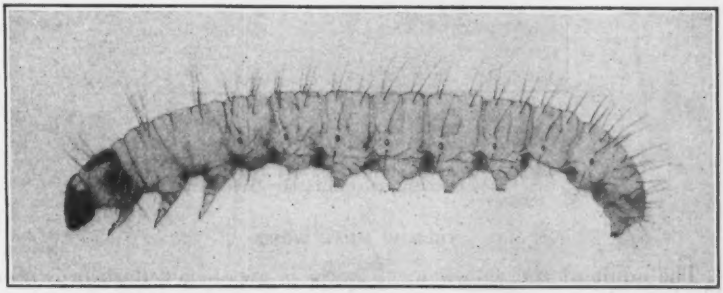

FIGURE 25.—Full-grown larva of the rice moth. The full-grown larva is about one-half inch long, and is of a whitish or bluish gray color. Much enlarged. (Chittenden)

was harvested during rainy weather or so stored that the moisture content was unusually high. Attempts to rear the moth in dry, warm laboratories have failed. The larvæ cut through burlap sacking and can damage sacks greatly when heavy infestations develop in sacked material. Figure 33 shows the characteristic webbing together of infested seeds—in this instance navy beans—and Figure

32 shows the tendency for larvæ to spin their whitish silken cocoons on the outside of grain sacks where the sacks touch each other.

MEAL WORMS

There are two species of meal worms in the United States. The adults are the largest of the beetles found in grain and their larvæ are conspicuous, for they attain a length of about 1 inch and are as large around as an earthworm.

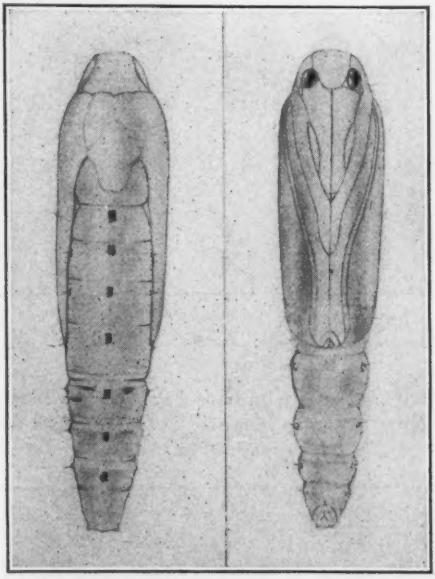

FIGURE 26.—Pupa of the rice moth: At left, dorsal view; at right, ventral view. The pupa is found in a dense tough cocoon into the walls of which have been spun particles of the food. The cocoons of the Indian meal moth, on the other hand, are very loosely constructed. Much enlarged. (Chittenden)

YELLOW MEAL WORM

The adult of the yellow meal worm is a polished dark-brown or black beetle, somewhat more than half an inch long, with its thorax finely punctured and with its wing covers longitudinally striated or grooved. (Fig. 34, right.) The females lay bean-shaped white eggs covered with a sticky secretion that causes the flour, meal, or grain waste in which they are placed to adhere to them. The eggs hatch in about two weeks into slender white larvæ, which soon turn yellow and assume the form shown in Figure 34. When full grown, the larvæ are about an inch long and yellowish, shading to yellowish brown toward each end and at the articulation of each segment. The pupa into which the larva transforms before becoming an adult beetle is shown in Figure 34.

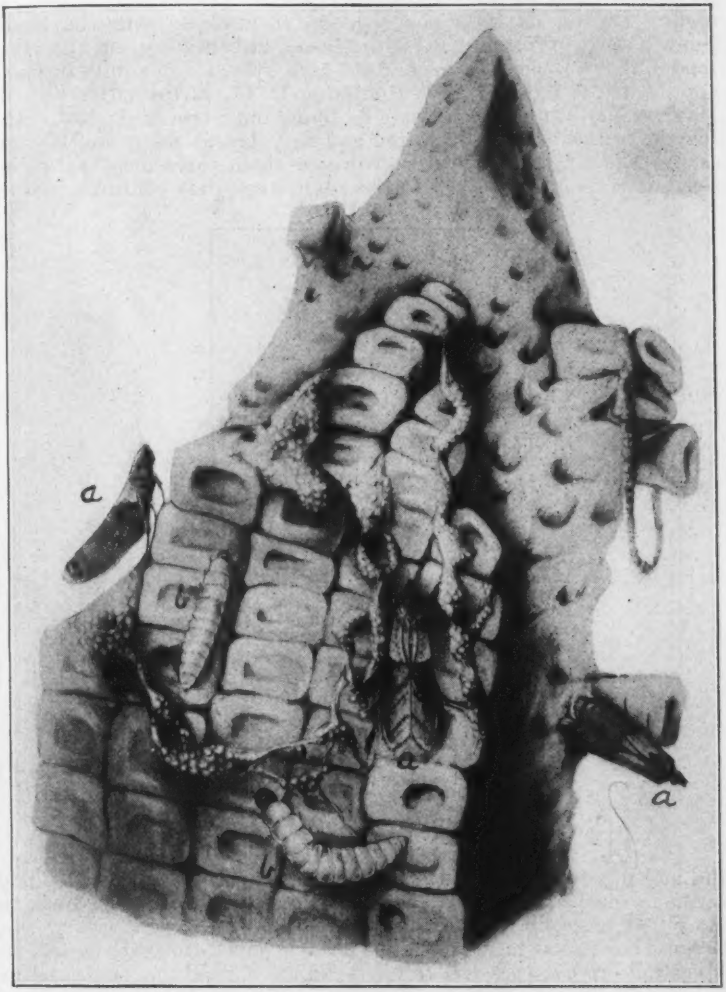

FIGURE 27.—The Indian meal moth: Tip of ear of corn showing, *a*, three moths with their characteristic light and dark markings, and *b*, two well-grown larvæ. The adult moth is distinguished from all other grain-infesting moths by having the outer two-thirds of its wings brownish and the inner third whitish gray. It has a wing spread of about three-fourths of an inch

The yellow meal worm, *Tenebrio molitor* L., is widespread over the world and is frequently found in stored grains. It belongs to a family of beetles (Tenebrionidae) known as the darkling beetles because of their preference for dark places. The adults fly only at night. During daylight they conceal themselves, with the larvæ, beneath sacks of grain, under grain boxes, or beneath grain and other food. There is but one generation each year. The adults begin to appear in the latitude of Washington, D. C., in the latter part of May and early in June and may be found until late in August. The female beetles are quite prolific and may lay as many as 500 eggs each. The larvæ become full grown in about three months, but instead of transforming then to the adult stage they continue feeding

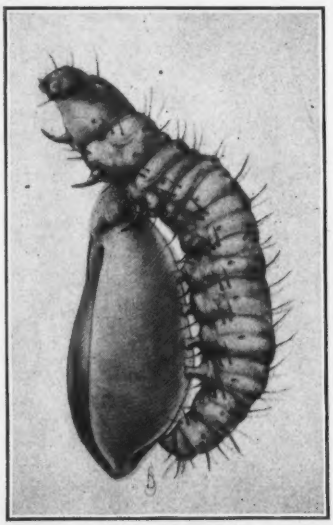

FIGURE 28.—Well-grown larva of the Indian meal moth, crawling on kernel of wheat. These worms are white or greenish in color and frequently eat out the germ end of wheat. They attain a length of about half an inch

and molting until cold weather and then hibernate as larvæ. In late spring or early summer of the following season they transform to the pupal stage, in which stage the insect passes about two weeks. Because the yellow meal worm has but one generation each year, and is entirely an external feeder upon grains, it need not be feared as a serious pest. Screening and fanning will remove it easily from grain shipments. The well-grown larvæ, however, can do serious injury to whole grains under certain conditions when grain is held for long periods without being moved.

DARK MEAL WORM

The dark meal worm, *Tenebrio obscurus* Fab., as may be seen by the larva, pupa, and adult shown in Figure 35, is very similar in

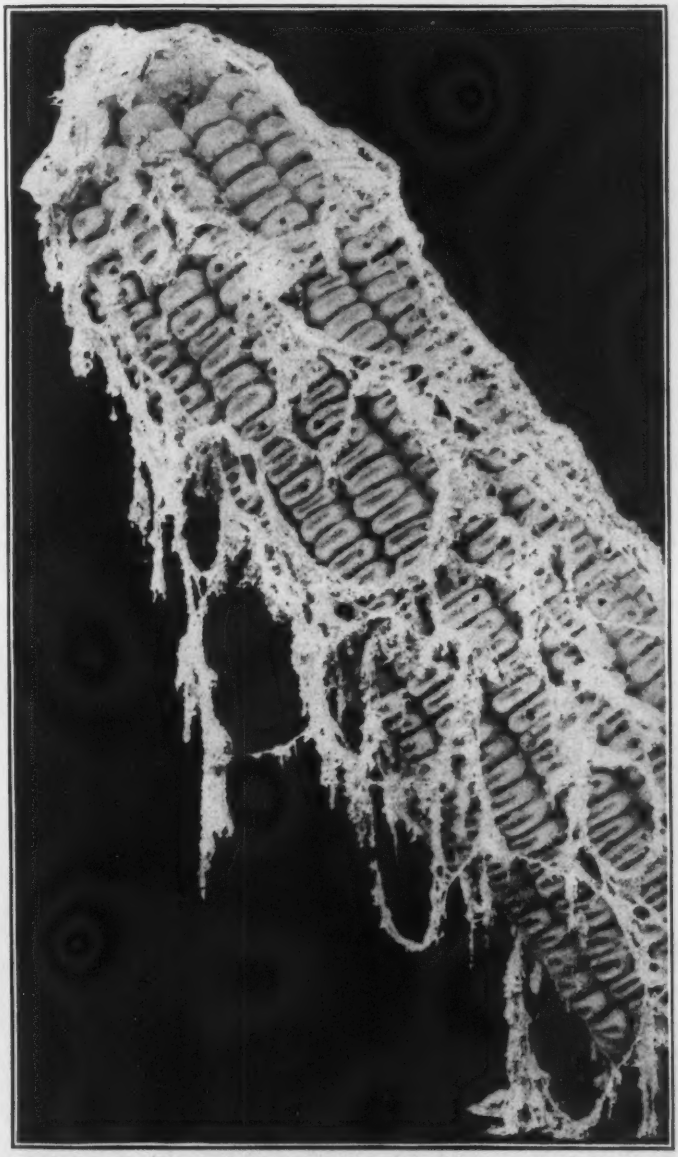

FIGURE 29.—Ear of corn showing the loose webbing characteristic of the Indian meal moth larvæ. This moth rarely attacks sound grain, but, as is here shown, frequently attacks grains already injured by other grain pests. Such webbing as is here shown develops only when corn or other grains are left unmoved for some time

form, size, and color to the yellow meal worm, to which it is closely related. The adult beetle differs, however, in being dull pitchy black, in contrast to the shiny or polished dark brown or black of

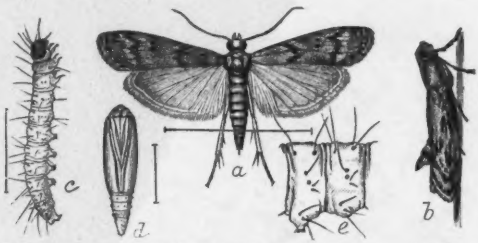

FIGURE 30.—The Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa (enlarged); *e*, abdominal joint of larva (more enlarged). The adult moth, with a wing expanse of a trifle less than 1 inch, is leaden gray in color, marked with transverse wavy black markings. The full-grown larva is whitish or pinkish in color, with small black spots, and is about one-half an inch long. (Chittenden)

the yellow meal worm. Its larva so closely resembles the larva of the yellow meal worm that it can be distinguished most easily by its much darker color.

The two species of meal worms are often found associated since they have similar feeding habits. The overwintering larvæ of the

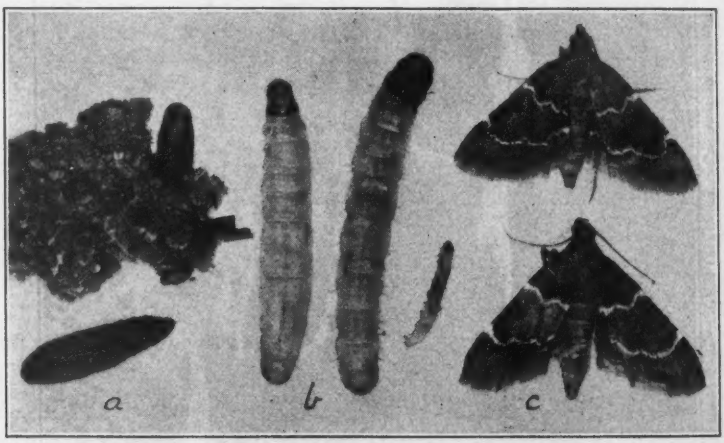

FIGURE 31.—The meal snout moth: *a*, Pupa and, above, webbed mass of grain showing portion of pupa protruding; *b*, two well-known larvæ with a smaller larva at right; *c*, two adult moths. Magnified about one and one-half times. The markings on the forewings easily distinguish this insect from other grain pests

dark meal worm begin to pupate earlier in the season than the yellow meal worms, and the adult beetles emerge during April and May in the vicinity of Washington.

FIGURE 32.—Inside of a grain sack that was filled with infested vetch seed. Note vetch seeds sticking to side of bag as a result of the webs of the larvæ of the meal snout moth, the numerous whitish cocoons with dark pupæ within, and, in the center, one adult moth. Natural size

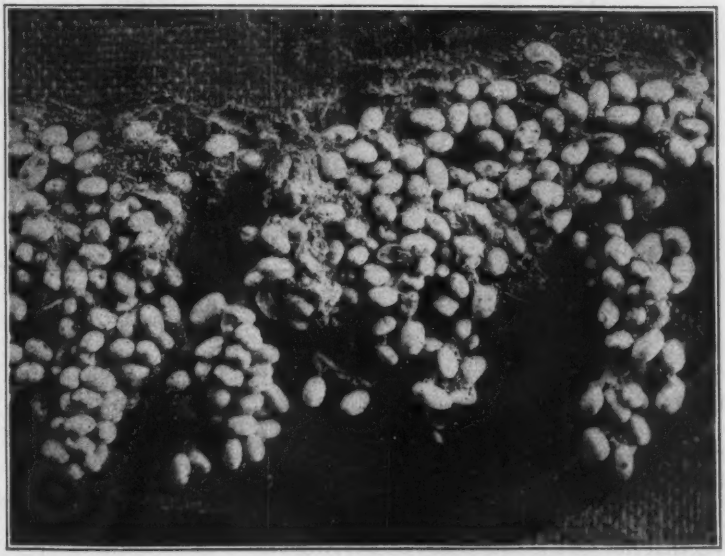

FIGURE 33.—Navy beans webbed together by larvæ of the meal snout moth, and adhering to sack. The larvæ often cut sacks so seeds fall out and lodge where sacks touch each other. In these places the seeds are usually more heavily infested

GRAIN AND FLOUR BEETLES

CADELLE

The cadelle, *Tenebroides mauritanicus* L., is an elongate, oblong, flattened, black or blackish beetle about one-third of an inch long. It resembles the meal worms in appearance, but is much smaller and the thorax and abdomen are loosely joined. (Fig. 36.)

The larva of the cadelle is one of the largest of the grain-infesting insects and is easily recognized. It is about three-quarters of an inch long, fleshy, with the abdomen terminating in two dark horny points.

FIGURE 34.—The yellow meal worm. Four well-grown larvæ, two pupæ, and the black adult beetle, with five kernels of wheat to indicate relative size. The larvæ when full grown are about 1 inch long and yellowish. The adult beetles are shiny black and slightly more than half an inch long

The larva is a dirty or chalk white, with head, thoracic shield, and the two horny points at end of body black, as shown in Figure 37.

This insect is widespread over the world and is frequently found in mills, granaries, and storehouses, where it infests flour, meal, grain, etc. Both larva and adult feed on grain and have the destructive habit of going from kernel to kernel and devouring the embryo. The cadelle often becomes well established in ear corn (fig. 38) that has first been injured by the Angoumois grain moth or by the weevils. The long slits in corn kernels shown in Figure 38 are char-

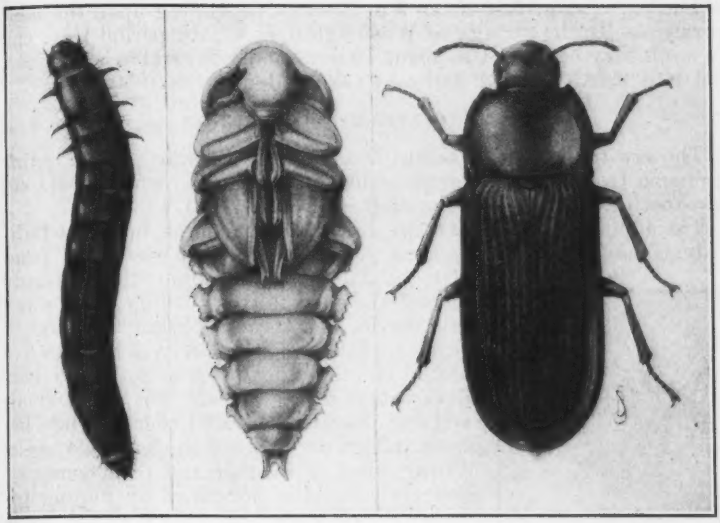

FIGURE 35.—The dark meal worm: *a*, Full-grown larva; *b*, pupa; *c*, adult beetle. Distinguished from the yellow meal worm by the dark brown color of the larva and the dull, not shiny appearance of the adult beetle. For true relative size of the larva, pupa, and adult compare with Figure 34

acteristic of cadelle infestation. The cadelle is one of the longest lived of the insects that attack stored grain; many of the adults live for more than a year, and some of them for nearly two years. The female beetles oviposit during the greater part of their lives and under favorable conditions will lay about 1,000 eggs each.

The white eggs are laid in clusters in the food material and hatch in from 7 to 10 days in warm weather. The larvæ complete their growth in from 2 to 14 months, then seek some secluded place in which to transform to the pupal stage (fig. 39), frequently boring into the timbers of the bin or other receptacle that holds the infested material. Both larvæ and adults can live for considerable periods without food, frequently remaining hidden in the woodwork of the bins for a long time after the grain has been removed. When new grain is put into such a bin it becomes infested in a surprisingly short time.

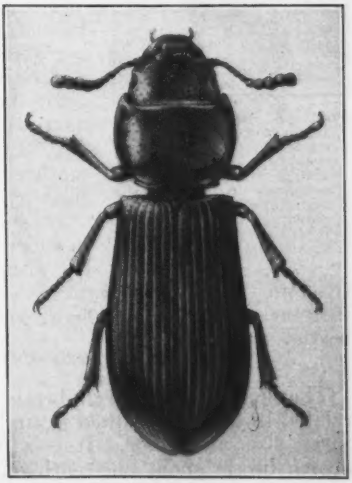

FIGURE 36.—The cadelle: Adult beetle. The cadelle is a flattened, black beetle about one-third of an inch long

The pupal stage lasts from 8 to 25 days, depending upon the temperature. In the vicinity of Washington, D. C., the period from egg to adult may be passed in about 70 days under favorable conditions, but it is usually longer and may take as long as 400 days.

SAW-TOOTHED GRAIN BEETLE

The saw-toothed grain beetle, *Oryzaephilus surinamensis* L., gains its name from the peculiar structure of the thorax, which bears six saw-tooth-like projections on each side. (Fig. 40.)

The adults live, on an average, from 6 to 10 months, but some individuals may live as long as three years. The female beetles lay from 100 to 200 eggs, dropping them loosely among the foodstuff or tucking them away in a crevice in a kernel of grain. The small, slender, white eggs hatch in from three to five days. The emerging larvæ do not spend their lives within a single grain, but crawl about actively, feeding here and there. They become full grown (fig. 40) in about two weeks during summer weather and then construct delicate cocoonlike coverings by joining together small grains or fragments of foodstuffs with a sticky secretion. Within this pupal cell the larva changes to the pupal stage, which last about a week. Development from egg to adult may take place in from three to four weeks in summer.

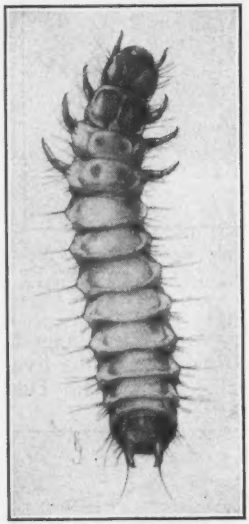

FIGURE 37.—The cadelle: Larva. Commonly found crawling among grain kernels. It may appear glistening white or dull and powdered according to the material in which it is crawling. When full grown it is about three-fourths of an inch long

MERCHANT GRAIN BEETLE

The merchant grain beetle, *Oryzaephilus mercator* Fauv., closely resembles the preceding species and has similar food habits. It differs in appearance from the saw-toothed grain beetle (fig. 41) chiefly by the much narrower, more sharply projecting temples (fig. 42, *a*) and in having the head and trochanters (second joint from the base in the leg) of the male unarmed.

It is apparently not so widely distributed in this country as the saw-toothed grain beetle, although the close resemblance between the two species may many times have resulted in the crediting of infestations of the merchant grain beetle to the saw-toothed grain beetle.

SQUARE-NECKED GRAIN BEETLE

The square-necked grain beetle, *Silvanus gemellatus* Duv., is closely related to the saw-toothed grain beetle, which it greatly resembles in form, size, and color. It is a flattened, oblong, polished, reddish-brown beetle about one-tenth of an inch long. It differs from the saw-toothed grain beetle by having the thorax almost square in shape and lacking the saw-toothlike projections. (Fig. 43.)

This beetle is chiefly abundant in the South, where it is found in great numbers outdoors infesting the seed pods of a great variety of plants. It is one of the most common beetles in stored corn in the South and in the cornfields is always to be found on damaged or exposed ears. The immature stages closely resemble those of the preceding species both in form and in habit. The larvæ have the bad habit of devouring the germ of the seed in which they breed. They can develop from egg to adult in about three weeks.

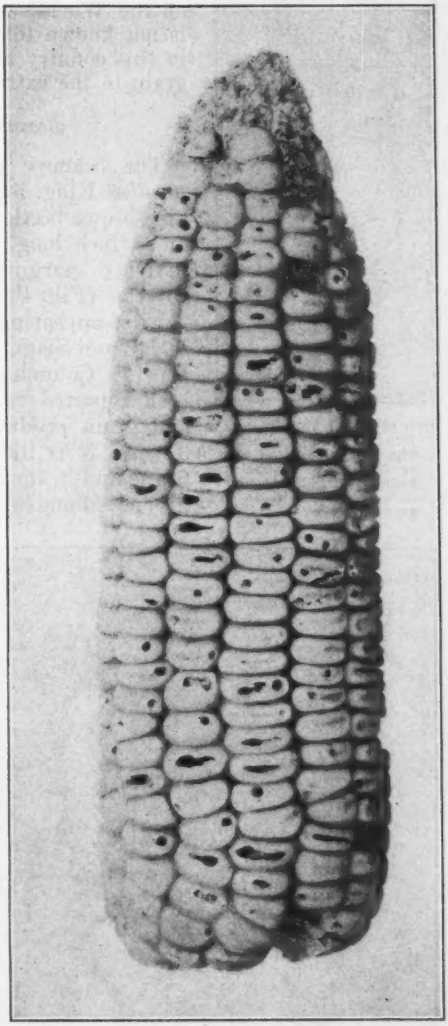

FIGURE 38.—Ear of corn infested by the Angoumois grain moth (round holes in kernels) and the cadelle. The elongated slits in the kernels are characteristic of cadelle feeding and emergence. Only ear corn stored for several years will develop this evidence of cadelle attack

FOREIGN GRAIN BEETLE

The foreign grain beetle *Cathartus advena* Waltl., is a small reddish-brown beetle somewhat similar in appearance to the preceding species, to which it is closely related. It differs from it by being smaller and more robust. (Fig. 44.) Although of world-wide distribution, it is of little consequence as an enemy of stored grains. It is attracted to damp and moldy grains and feeds on the molds developing in such grains. It is rarely found in clean grain.

MEXICAN GRAIN BEETLE

The Mexican grain beetle, *Pharaxonotha kirschi*, Reitt., is a highly polished, deep-brown beetle about three-sixteenths of an inch long. While resembling somewhat the confused flour beetle in general appearance, it can be readily distinguished by its more polished surface and by its longer antennæ. (Fig. 45.)

FIGURE 39.—The cadelle: Pupa, much enlarged. The pupa is seldom seen, as this stage of the cadelle's life cycle is spent in a cell made in an inaccessible place

This insect is common in Mexico, where it breeds in grain and grain products. It was found in this country in grain exhibits at the World's Columbian Exposition, but is not known to be permanently established in this country as yet. It may be found in grain in the extreme South.

SIAMESE GRAIN BEETLE

The Siamese grain beetle, *Lophocateres pusillus* Klug, is an elongate, flattened, reddish-brown beetle slightly less than an eighth of an inch long, characterized by the much flattened margins of the thorax and wing covers. (Fig. 46.)

First appearing in exhibits of rice and cereals from Siam, Liberia, and Ceylon at the World's Columbian Exposition, it has since been reported as injurious to stored grain and grain products in South Carolina and Texas. It is likely to be found in seaport towns and in the Southern States, but as yet it is not abundant or widespread.

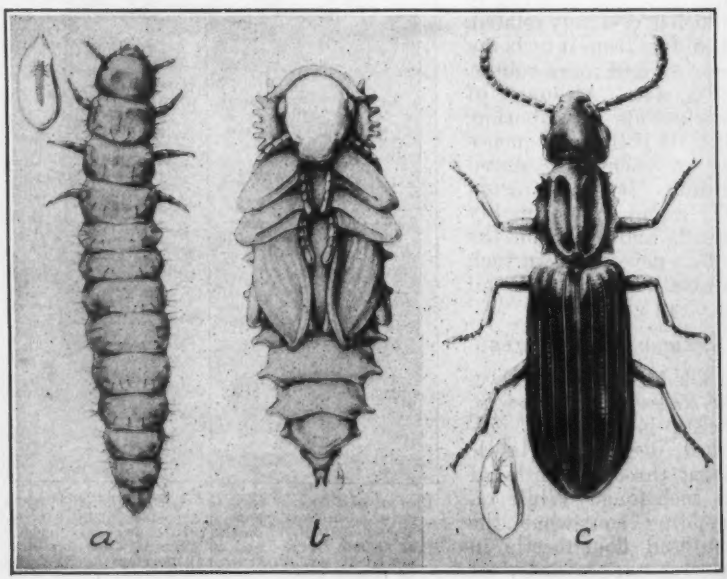

FIGURE 40.—The saw-toothed grain beetle: *a*, Well-grown larva, with kernel of wheat to show its relative size; *b*, pupa; *c*, adult beetle with kernel of wheat to show its relative size. The adult beetle, about one-tenth of an inch in length, can be easily recognized by the six toothlike projections on each side of the thorax

FLAT GRAIN BEETLE

The flat grain beetle, *Cryptolestes pusillus* Schön., is a small flattened, oblong, reddish-brown beetle about one-sixteenth of an inch long, with elongate antennæ somewhat longer than half the

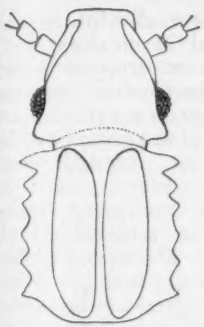

FIGURE 41.—Head and thorax of saw-toothed grain beetle

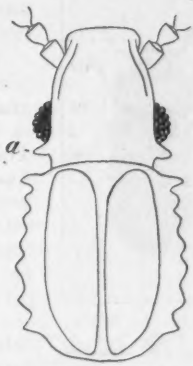

FIGURE 42.—Head and thorax of merchant grain beetle. Note the narrow, sharply projecting temples at *a*

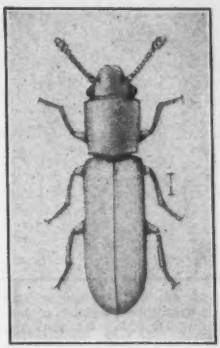

FIGURE 43.—The square-necked grain beetle. (Chittenden)

FIGURE 44.—The foreign grain beetle. (Chittenden)

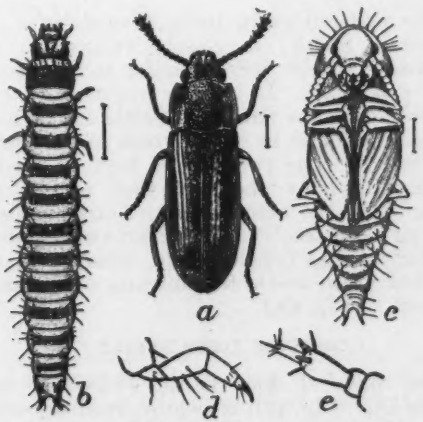

FIGURE 45.—The Mexican grain beetle: *a*, Beetle; *b*, larva; *c*, pupa; *d*, leg of larva; *e*, antenna of larva. *a*, *b*, *c*, Much enlarged; *d*, *e*, more enlarged

length of its body. (Fig. 47.) It is readily distinguished because it is the smallest beetle commonly found in stored grain in this country. It is cosmopolitan in distribution, is very generally found in stored corn in the South, and is often screened from wheat shipments. It is not a primary pest of stored grain, and the adult is

apparently unable to survive in sound, uninjured grain. It follows up the attack of the more vigorous grain pests and is frequently found associated with the rice weevil in enormous numbers. It is a scavenger by nature and often infests grain and meal that is out of condition.

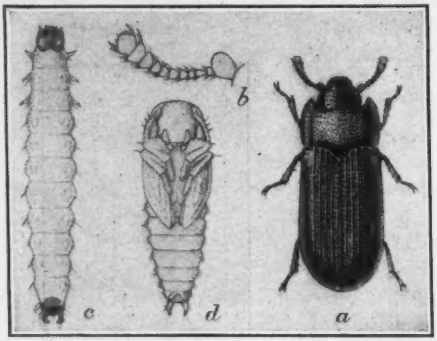

FIGURE 46.—The Siamese grain beetle. *a*, Beetle; *b*, antenna of same; *c*, larva; *d*, pupa. *a*, *c*, *d*, About 10 times natural size; *b*, greatly enlarged

The small white eggs are placed in crevices in the grain or dropped loosely in farinaceous material. The larvæ are particularly fond of the germ in wheat, and in infested grain many kernels will be found uninjured except for the removal of the germ. The larvæ also feed on dead insects. When fully grown the larvæ form cocoons of a gelatinous substance to which food particles adhere. They transform to the pupal stage in these cocoons and later emerge as adults.

RUST-RED GRAIN BEETLE

The rust-red grain beetle, *Cryptolestes ferruginous* Steph., is closely related to the preceding species and is similar to it in form, size, and habit. It is more resistant to cold weather than the flat grain beetle and is more commonly found in stored grain in the Northern States. The two species may be readily distinguished by the fact that in the flat grain beetle the antenna of the male is about as long as the body and is about twice as long as that of the female beetle, whereas in the rust-red grain beetle the antenna of the male is short. (Fig. 48.)

FIGURE 47.—Adult of the flat grain beetle, showing characteristic long antennæ. Not more than one-sixteenth of an inch long. This beetle is one of the very smallest found in grain shipments

CONFUSED FLOUR BEETLE

The confused flour beetle, *Tribolium confusum* Duv. (fig. 49), is a shiny, reddish-brown beetle about one-seventh of an inch long, flattened and oval in form, with head and upper parts of thorax densely covered with minute punctures and with wing covers ridged lengthwise and sparsely punctured between the ridges. It is generally distributed over the world and is very abundant in all parts of this country. It is known as one of the flour beetles owing to its frequent occurrence in flour. It is a general feeder on starchy foods and is probably the worst insect pest of prepared cereal foods. It is

constantly found in granaries, mills, and storehouses, and grain shipments.

The minute white eggs of this beetle are laid in the cracks and crevices of bins, barrels, boxes, or other containers of the foodstuffs attacked by this insect. They are covered with a sticky secretion, so that they become covered with flour, meal, etc., and readily adhere to the sides of sacks, boxes, and other containers so fresh material placed in them is rapidly infested. The eggs hatch into small worm-like larvæ, slender, cylindrical, and wiry in appearance. When fully grown they are about three-sixteenths of an inch long, and in color are white, tinged with yellowish. These larvæ feed on flour or other material such as grain dust and the broken surfaces of grain kernels. When full grown they transform to small naked pupæ. At first white, the pupæ gradually change to yellow and then brown, and shortly afterwards transform to beetles. The period from egg to adult in summer is about four weeks under most favorable weather conditions, though the life cycle is greatly prolonged by cold weather, as is true of all grain pests.

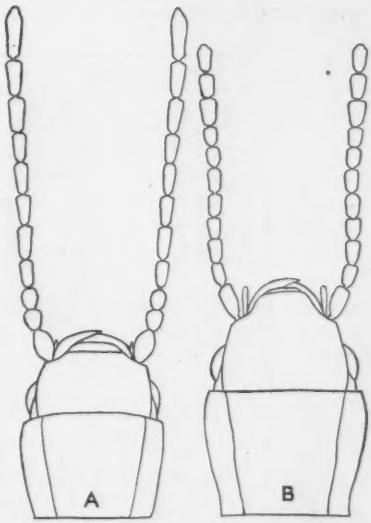

FIGURE 48.—Thorax, head, and antennæ of male beetles, showing the relative length of the antennæ as compared with those parts of the body in—*a*, the flat grain beetle; *b*, the rust-red grain beetle

RUST-RED FLOUR BEETLE

The rust-red flour beetle, *Tribolium ferrugineum* Fab., is almost identical in appearance with the preceding species, to which it is closely related. It can be distinguished from the confused flour beetle only with the aid of a magnifying glass. The segments of the antennæ of the confused flour beetle increase in size gradually from the base to the tip, while in the rust-red flour beetle the last few segments of the antennæ are abruptly much larger than the preceding ones, giving the antennæ the appearance of being suddenly enlarged at the tip. In addition, the margins of the head of the confused flour beetle are expanded and notched at the eyes, while the margins of the head of this species are nearly continuous at the eyes. The differences between the two species are clearly shown in Figure 49, *e* and *f*.

This insect is similar to the confused flour beetle in feeding and breeding habits, and it is impossible to distinguish between the early stages of the two insects. Although cosmopolitan in distribution, it is found more commonly in the South, where it causes very serious damage to grain products. In addition to the actual damage caused by its feeding activities, serious losses are caused by the nauseous

smell and taste that it imparts to the material it infests. Like the confused flour beetle, the rust-red flour beetle is primarily a pest of milled products, and while present in grain shipments it confines its attack in these to grain dust and the surface of broken grains, hence is not a primary pest of commercial shipments.

LONG-HEADED FLOUR BEETLE

The long-headed flour beetle,[1] *Latheticus oryzae* Waterh., is a slender, flattened beetle, slightly less than an eighth of an inch long, somewhat similar in form to the confused flour beetle but pale yellow and further differentiated by the peculiarly shaped antennæ shown in Figure 50 and by the minute canthus behind each eye. It has been reported from most parts of the world infesting wheat, rice, corn, barley, rye, flour, etc. It was first recognized in this country

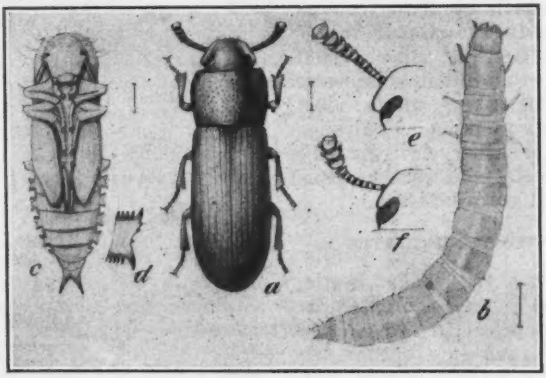

FIGURE 49.—The confused flour beetle, the commonest insect recovered from grain shipments. It is about one-sixth of an inch long. *a*, Beetle; *b*, larva; *c*, pupa; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle, showing antenna; *f*, same of the rust-red flour beetle. (Chittenden)

about 13 years ago from specimens taken in Texas. It is not known to be very widely distributed in the United States, but is likely to be found in mills and granaries in the South.

BROAD-HORNED FLOUR BEETLE

The broad-horned flour beetle, *Gnathocerus cornutus* Fab., owes its name to the peculiar structure of the mandibles or jaws of the male beetle, which are armed with a pair of broad, stout horns as shown in Figure 52. It is a robust, reddish-brown beetle, about one-sixth of an inch long; closely resembling the other flour beetles in appearance, but easily distinguished by the peculiar structure of the jaws. It is cosmopolitan in distribution and occurs frequently in the Southern States. It prefers to feed in flour and meal, but is found in a variety of grains. The adult beetles frequently live for a year or longer, the females laying from 100 to 200 eggs each. The small

[1] A closely related species, *Latheticus prosopsis* Chittn., is shown in Figure 51.

white eggs hatch in from four to five days in warm weather, and development from egg to adult takes place in about eight weeks.

SLENDER-HORNED FLOUR BEETLE

The slender-horned flour beetle, *Gnathocerus maxillosus* Fab., is closely related to the preceding species and is of similar form and

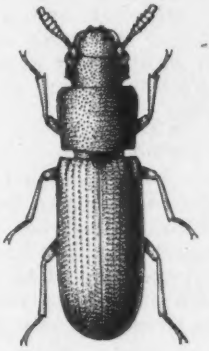

FIGURE 50.—Long-headed flour beetle. (Chittenden)

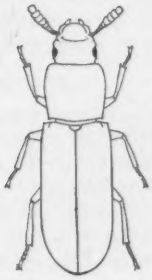

FIGURE 51.—*Latheticus prosopis*. (Chittenden)

FIGURE 52.—The broad-horned flour beetle. (Chittenden)

appearance. It is about one-eighth of an inch in length, and, in addition to its smaller size, it may be distinguished from the broad-horned flour beetle by the shape of the horns with which the mandibles or jaws of the male are armed. In this species (fig. 53) the horns are slender and incurved. Its habits are similar to those of the preceding species.

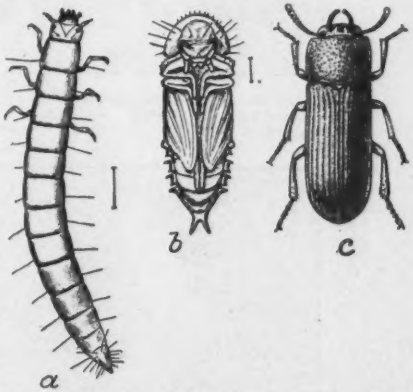

FIGURE 53.—The slender-horned flour beetle: *a*, Larva; *b*, pupa; *c*, beetle. (Chittenden)

SMALL-EYED FLOUR BEETLE

The small-eyed flour beetle, *Palorus ratzeburgi* Wissm. (fig. 54), is the smallest of the so-called flour beetles that infest grain and grain products in this country. It is a tiny, flattened, shiny, reddish-brown beetle, somewhat oblong in form and measuring about one-twelfth of an inch in length. It occurs throughout the world and is widely distributed in this country. It prefers ground products in which to breed, but is not infrequently found in stored grains.

A closely related species (*P. depressus* Fab.) more common in Europe but occasionally found in this country is very similar in appearance and habits to the small-eyed flour beetle.

TOBACCO BEETLE

The tobacco beetle, *Lasioderma serricorne* Fab., is a small, robust, oval, reddish-yellow or brownish-red beetle, with head bent down nearly at right angles to the body, giving the beetle a humped appearance when viewed from the side as shown in Figure 55. It varies in size, but is usually about one-tenth of an inch long. It is found in all temperate, subtropical, and tropical regions and infests tobacco and many other stored products. It breeds in a variety of seeds and may occasionally be found attacking grains left long in storage in original sacks.

FIGURE 54.—The small-eyed flour beetle. (Chittenden)

DRUG-STORE BEETLE

The drug-store beetle, *Sitodrepa panicea* L., is very similar in appearance to the tobacco beetle, to which it is closely allied, but differs from it by being more elongate in proportion and in having the wing covers distinctly striated. It is about one-tenth of an inch long. It is cylindrical and uniform light brown; its body is covered with a fine silky pubescence. (Fig. 56.) The larva or grub is very

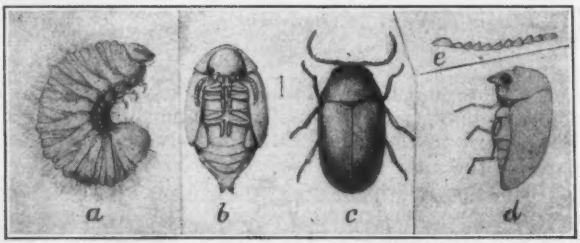

FIGURE 55.—The tobacco beetle never attacks grain unless it has been stored for long periods. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden)

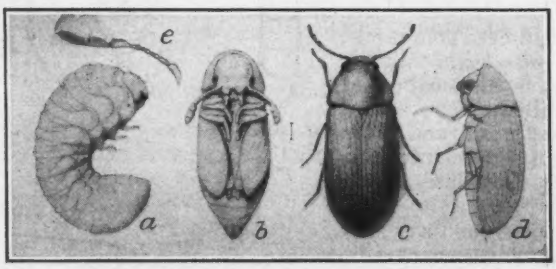

FIGURE 56.—The drug-store beetle never attacks grain unless it is stored for long periods unmolested. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden)

much less hairy than that of the cigarette or tobacco beetle, as a comparison of Figures 57 and 58 will show. It is known as the drug-store beetle from its habits of feeding on almost all drugs found

in pharmacies. It is a very general feeder, attacking a great variety of stored foods, seeds, and other materials, and has been said to "eat anything except cast iron." It is frequently found in storehouses and granaries in all parts of the world.

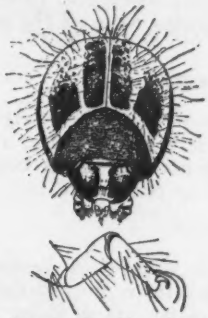

FIGURE 57.—The tobacco beetle: Head and leg of larva. (Chittenden)

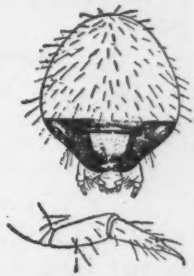

FIGURE 58.—The drug-store beetle: Head and leg of larva. (Chittenden)

The eggs of this beetle are laid in almost any dry organic substance. The small white grubs emerging from the eggs tunnel through these substances and when full grown pupate in small cocoons. The entire life cycle may be passed in less than two months.

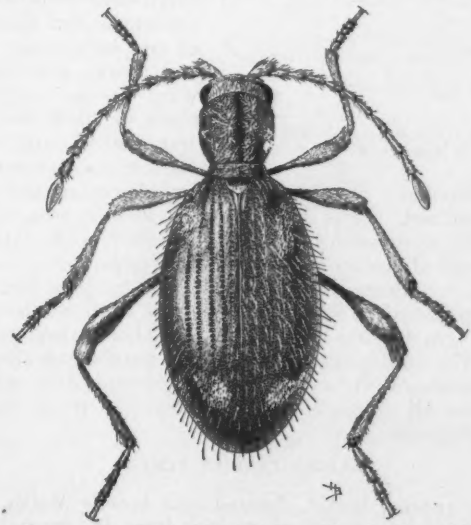

FIGURE 59.—The white-marked spider beetle, adult female. (The male is elongate-oval in shape and is not so conspicuously marked as the female)

WHITE-MARKED SPIDER BEETLE

The white-marked spider beetle, *Ptinus fur* L. (fig. 59), is occasionally found infesting stored grain and seeds of various kinds, but rarely causes serious damage. It is an omnivorous feeder, attack-

ing flour, meal, roots, seed, and miscellaneous stored foods. It is about an eighth of an inch in length, reddish brown with four white marks on the wing covers, and, owing to the length of its legs and antennæ, has a somewhat spidery appearance. The larva is white and closely resembles those of the tobacco beetle and the drug-store beetle. It has the habit of forming globular cases of the material in which it is feeding.

BROWN SPIDER BEETLE

The brown spider beetle, *Ptinus brunneus* Dufts., closely resembles the preceding species in size, color, general appearance, and habits. It may be distinguished from the white-marked spider beetle by the fact that the white markings of the wing covers are lacking.

CATORAMA BEETLE

Another beetle closely related to the drug-store beetle and the tobacco beetle and which has similar habits is the catorama beetle, *Catorama* sp., which is shown in Figure 60. It is shiny black and is about one-eighth of an inch long. It is only an occasional pest of stored grain and does not cause serious damage.

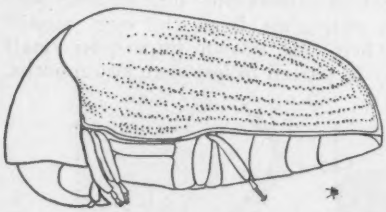

FIGURE 60.—The catorama beetle. This beetle is shiny black

BLACK CARPET BEETLE

The black carpet beetle, *Attagenus piceus* Oliv., is a small oval beetle between two-sixteenths and three-sixteenths of an inch long. The head and thorax are black, but the wing covers may be either black or dark reddish brown, and clothed with short hairs. Its legs and antennæ are dark yellowish in color. The larva is very characteristic and can be readily recognized. It is reddish or golden brown, clothed with short scalelike appressed hairs and provided with a tuft of long hairs at the end of the body, as shown in Figure 61.

As the name indicates, this insect injures carpets, but in addition it is known to breed in grains and cereals, both whole and ground. The larval stages develop very slowly, and there is but one generation each year. The adults appear in greatest numbers during the spring and early summer. It occurs in Europe and Asia and has been reported from all parts of this country. It is of very common occurrence in houses.

LARGER CABINET BEETLE

The larger cabinet beetle, *Trogoderma tarsale* Melsh., is a small, oval beetle about one-eighth of an inch long, its ground color black mottled with reddish brown, covered with gray and light-brown scalelike hairs forming a distinct pattern on the wing covers. The larva somewhat resembles that of the black carpet beetle in appearance. It is about one-eighth of an inch long, reddish brown above and whitish beneath, with body covered with short yellowish-brown

hairs and with a tuft of short hairs at the tail end. (Fig. 62.) It is well known for its habit of breeding in dead insects and animal substances and is not infrequently found living in grain, flaxseed,

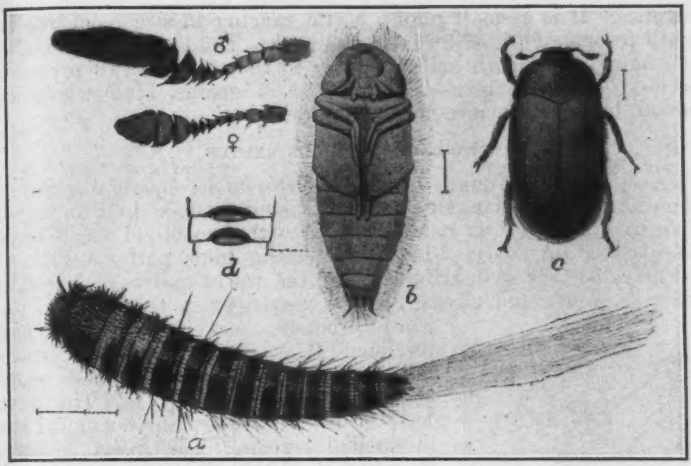

FIGURE 61.—The black carpet beetle is chiefly a pest of sample grains, or found in grain dust about elevators or storage bins. *a*, Larva; *b*, pupa; *c*, beetle; *d*, dorsal abdominal segments of pupa; ♂, antenna of male beetle; ♀, antenna of female beetle. (Howard)

castor beans, pumpkin seed, etc. It often becomes a nuisance in laboratories by attacking sample lots of corn, wheat, etc.

SMALL CABINET BEETLE

The small cabinet beetle, *Anthrenus verbasci* L., is somewhat similar in appearance to the larger cabinet beetle but smaller and of different color. It varies in length from one-sixteenth to two-sixteenths of an inch, and is black with yellowish-white scales that form a broad band across the back and give the body a mottled appearance. The habits of the adult and early stages of this insect are similar to those of the larger cabinet beetle. It is occasionally found in flour mills and granaries, where it infests grain and grain products.

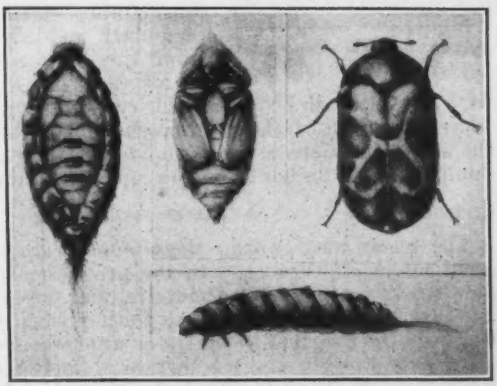

FIGURE 62.—The larger cabinet beetle: At left, pupa within larva skin; in center, pupa; at right, beetle; below, well-grown larva

MUSEUM BEETLE

The museum beetle, *Anthrenus museorum* L., is closely allied to the preceding beetle and resembles it in size and form. Its body is black, covered with yellowish and whitish scales, giving it a spotted appearance. It is a small plump beetle varying in size from one-sixteenth to one-eighth of an inch in length. The larvæ are small, active, hairy grubs with habits similar to those of the two preceding species. They are occasionally found in grains, both whole and ground, but do not cause noticeable damage.

TWO-BANDED FUNGUS BEETLE

The two-banded fungus beetle, *Alphitophagus bifasciatus* Say, is a handsome little elongate-oval beetle slightly less than an eighth of an inch long. It is reddish brown with two broad black bands across the wing covers. Its characteristic color pattern is shown in Figure 63. It is distributed over the world and is in general a feeder on fungi and molds, being a scavenger in refuse grain and grain products, decaying vegetable matter, etc. It is frequently found around mills and storehouses where waste material is allowed to accumulate. The larvæ have been bred from moist cornmeal and in spoiled cereals. The insect is often found in the holds of grain ships in wet or damaged grain.

FIGURE 63.—The two-banded fungus beetle. Adult

BLACK FUNGUS BEETLE

The black fungus beetle, *Alphitobius piceus* Oliv. (fig. 64), resembles the mealworm beetles in form and color but is considerably smaller. It is black or a very dark reddish brown and measures from three-sixteenths to four-sixteenths of an inch in length. The larva (fig. 64, *a*) is yellowish brown and is very similar in form and appearance to young larvæ of the meal worms. This beetle is often found in the same situations as the two-banded fungus beetle. It breeds in damp moldy grain but causes no injury to grain that is sound and dry.

LESSER MEAL WORM

The lesser meal worm, *Alphitobius diaperinus* Panz., is almost identical in appearance with the preceding species and has similar habits. It prefers spoiled material and does not cause serious damage to sound grain. It may be distinguished from the black fungus beetle by the fact that in the lesser meal worm the sides of the thorax are nearly straight and the surface is finely and sparsely punctured, whereas in the black fungus beetle the sides of the thorax are curved and the surface is coarsely and profusely punctured.

CORN SAP BEETLE

The corn sap beetle, *Carpophilus dimidiatus* Fab., may be readily recognized by its peculiar wing covers, which are short and truncate, leaving the tip of the abdomen exposed as shown in Figure 65. It is a

small, dark-brown beetle with lighter colored wing covers, oblong-ovoid in shape, and varying in length from one-tenth to one-eighth of an inch. It normally feeds in rotting and decaying fruit and vegetation and in the sap exuding from injured plants. It is quite numerous in

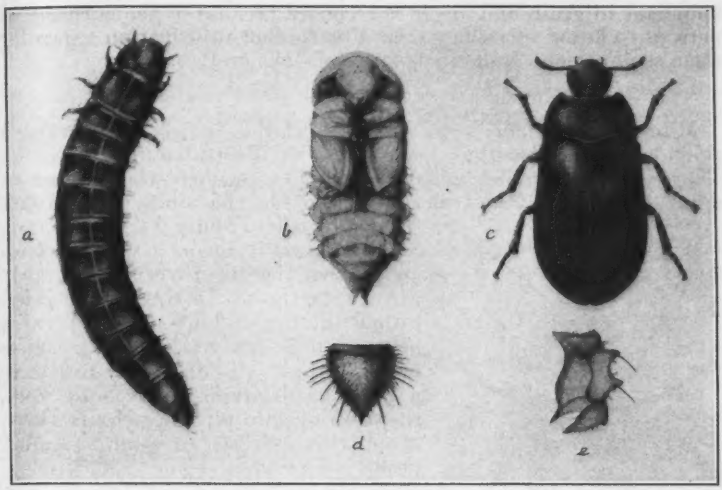

FIGURE 64.—The black fungus beetle: *a*, Larva; *b*, pupa; *c*, adult; *d*, caudal segment of larva (Schiödte); *e*, lateral plate of pupa. (Schiödte)

cornfields in the South, swarming over the damaged ears and feeding and breeding in the decaying kernels. It is attracted to damp and decaying grain but is seldom found in grain that is clean and dry.[2]

FIGURE 65.—The corn sap-beetle. Adult

A closely related beetle (*Carpophilus humeralis* Murray) that has been introduced from abroad and is becoming more and more abundant is similar in form to the corn sap beetle, but is slightly larger and is uniform, shiny, dark brown all over. Its habits are very similar to those of the preceding species.

BOOK-LICE OR PSOCIDS

Book-lice or psocids, *Troctes divinatoria* Fab. *et al.*, are minute, pale, soft-bodied, louselike insects, about one thirty-second of an inch long, with long, slender antennæ, differing greatly in appearance from other grain-infesting insects. (Fig. 66.) They may be whitish, almost transparent, or quite dark.

[2] *Carpophilus pallipennis* Say, a purely flower-infesting beetle, has been occasionally reported as infesting stored corn. In these cases large specimens of the corn sap beetle which closely resemble this species were probably mistaken for it.

Psocids are of very common occurrence and may be found in nearly any situation. They are almost omnivorous, feeding on any animal or vegetable matter. They are frequently found in grain, but while they have jaws and are capable of feeding upon solid materials, they may be disregarded as pests of grain. They are frequently very abundant in grain and are here recorded because of the curiosity of persons to know what they are. For further information regarding them see Farmers' Bulletin 1104, Book-Lice or Psocids.

MITES

Mites, *Tyroglyphus* spp., are pale-colored, soft-bodied creatures provided with numerous long hairs, as illustrated in Figure 67. They are microscopic in size. As a low estimate the number of mites that may be found on 1 square inch has been placed at 100,000.

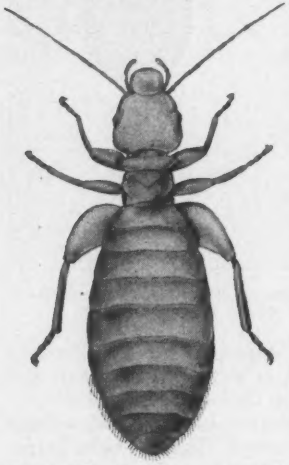

FIGURE 66.—Book-louse or psocid

They are often found in stored grain and occasionally increase with such rapidity that the grain seems to be fairly alive with them. During heavy infestations their cast skins and dead bodies accumulate in fluffy light-brown masses beneath the sacks of grain. If these accumulations are on a warehouse floor, they roll up into piles, which are blown about with each gust of wind. No other group of pests in grain will produce these masses. When present in large numbers they promote sweating, impart a disagreeable odor to the grain, and may cause damage by their feeding. Fortunately the mites that attack grain are themselves preyed upon by predacious mites which usually become abundant enough to kill the grain mites in a comparatively short time. If they do not, the screening and fanning of grain will usually reduce mite infestations to a point where no injury takes place.

PARASITES OF GRAIN PESTS

Grain in bulk is often seen swarming with small, black, wasplike insects of a size and appearance shown in Figure 68. These do not cause injury to grain. On the contrary, they are beneficial, as they are attacking and killing the grain weevils and grain moths. While parasites kill a large number of grain insects they unfortunately can not be considered of great importance from the standpoint of grain protection, for by the time the grain insects have been controlled by parasites the grain itself has become very badly damaged. For this reason the appearance of a large number of parasites in grain cars or elevators should be disregarded and the grain treated as though parasites were not present.

Grain dealers frequently find a small threadlike white worm, *Scenopinus fenestralis* L. (fig. 69), about three-quarters of an inch long in grain dust beneath sacks or in the bottoms of bins. This

is the larva of a small black fly to be found crawling upon windows of granaries and flour mills. Because of this habit it is called the window-pane fly. Its threadlike larva does no harm to grain but is predacious upon the larvæ of grain pests and clothes moths. It is not abundant enough to be of value in protecting grain.

HOW GRAIN BECOMES INFESTED

Grain may become infested in a number of ways. It is never possible to settle satisfactorily litigation over responsibility for insect damage to grain without a thorough knowledge of the history of the particular grain shipment involved.

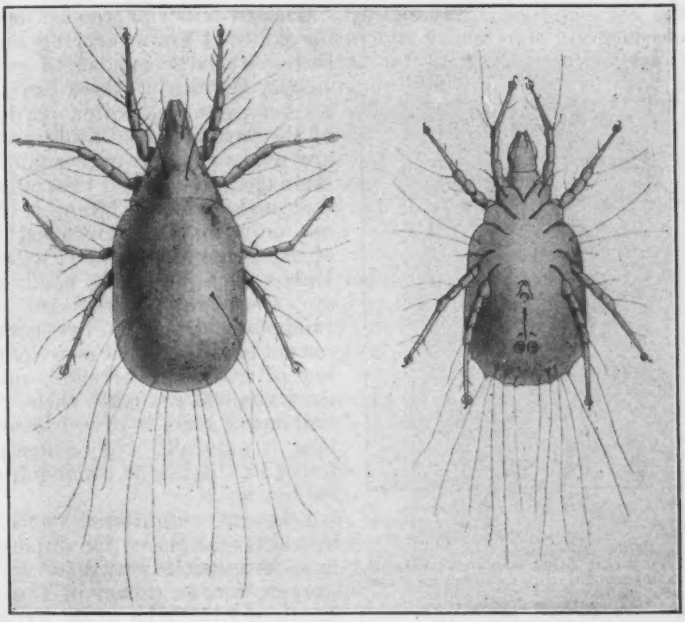

FIGURE 67.—Grain mites. (Howard)

Several of the worst insect pests of grain, notably the Angoumois grain moth and the rice or black weevil, fly to the grainfields from near-by cribs and begin their attack upon the maturing grain. In the case of wheat and similar small grains, the eggs of the insect are laid directly upon the heads of grain. In the case of corn the insects can infest only those kernels that are exposed because of poorly developed or damaged shuck covering. In cornfields, especially in the South, where insect infestation occurring in the field is most severe, there are a sufficiently large number of exposed kernels to bring about slight, though widespread, infestation.

It is probably true that in well-grown crops of corn the percentage of kernels infested before the crop is ready for harvest is very small, and throughout the Middle and Northern States is a negligible factor. In the Gulf Coast States, especially in upland fields, the infes-

tation often is very severe. In the case of wheat, grown particularly along the Ohio River, in southern New Jersey, in Pennsylvania, Maryland, Delaware, Virginia, and southward, the field infestation may be much more general than is now believed. Newly threshed wheat from Maryland arriving in September on the Baltimore market showed infestation ranging up to 6 per cent. While these infestations occurring in the grain before it is harvested are usually unavoidable, they are of great importance as "leaven" which in storage may result in a general infestation of an entire crop, in heating, and in much damage.

After grain has been harvested it is often stored in bins, storehouses, or barns that have held, or still hold, infested grain and which have not been thoroughly cleaned. Wooden bins and wooden partitions in grain storehouses and in the holds of grain-carrying ships become the nesting places for an incredibly large number of grain pests. Certain of these can and do bore into the softer portions of the partitions and timbers that are used over and over again as dunnage, and the excavations they make serve as hiding places, not only for themselves but all other species associated with them. Unless such bins and partitions are thoroughly disinfected by fumigants, these hidden insects can not be killed. The mere spraying of contact insecticides upon the walls will not reach them. If uninfested grain is placed in such bins, it naturally will become infested by the insects coming from the bin walls.

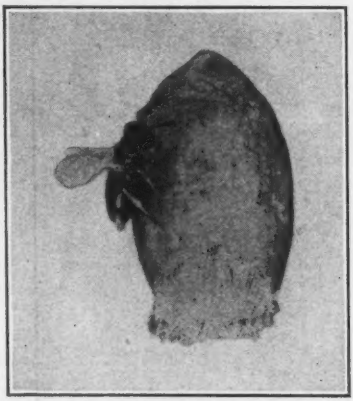

FIGURE 68.—Hymenopterous parasite of grain pests. Adult parasite resting upon a kernel of wheat. These tiny gnatlike insects are beneficial but their help usually comes too late to prevent damage to the crop in which they are most abundant

Likewise, uninfested grain should not be placed for shipment in sacks previously used for grain storage, for, as shown in Figure 32, these old sacks often harbor insects unless they have been treated by heat or fumigation. Certain extensive and costly infestations have been traced directly to the use of secondhand untreated grain sacks.

Grain stored in the open or in poorly constructed cribs or bins may become infested by insects flying in from outside sources.

HOW TO PREVENT PRIMARY INFESTATION

Infestation of grain in the field can not be entirely prevented, but by proper precautions it can be reduced to a minimum. The first generation of insects in the maturing grain is usually small, and if the grain is cut as soon as ripe, threshed as soon as dry, and then placed in storage in clean, deep bins the damage from this source will be very slight. It is when the grain is left in the field long after it is ripe that serious infestation results, for the insects increase in one or two generations to enormous numbers. In the case of corn

in the field, only those ears that are damaged or through poor shuck development have kernels exposed are subject to the attack of grain insects. Farmers should therefore grow a variety of corn that develops a long tight shuck.

Newly harvested small grains should not be stored unthreshed for any length of time, as in this condition they are very susceptible to infestation. If promptly threshed and stored in deep bins, only a thin layer on top of the bin is likely to become infested. Corn may be stored in the shuck if the husk is long and tight and fully covers the tip, but all ears with loose, broken, short, or damaged husks should be shucked and stored separately.

Clean grain should never be stored in old bins, granaries, or storehouses until they have been thoroughly cleaned and freed from the accumulations of waste grain and other materials harboring grain insects. Timbers in bins, granaries, or holds of ships that have become infested with grain insects should be destroyed or treated before being used again. Steel or concrete bins are highly desirable owing to the ease with which they are cleaned.

Bags of all kinds that have previously held grain should not be allowed in granaries or warehouses or be refilled until they have been sterilized by heat or otherwise freed from insects. The use of tight cribs will keep the grain free from infestation by insects that might fly in from the outside.

FIGURE 69.—Larva of a kind of fly that preys upon grain beetles and mites. This white threadlike worm is sometimes found in grain dust and attains a length of about three-fourths of an inch; while interesting, it is of no practical value

THE TREATMENT OF INFESTED GRAINS

Insects infesting stored grain can be destroyed by the use of heat, or by fumigation with poisonous gases. These remedial measures are mentioned only briefly in this bulletin.

HEAT

A temperature of 120° to 130° F., maintained for a short time, will kill all stages of grain-infesting insects, without injuring the germinating quality of the grain. Owing to the difficulty of subjecting the grain to such a temperature this method of control is used chiefly by millers and large grain dealers who are equipped with commercial driers suitable for the purpose.

FUMIGATION

Carbon disulphide, carbon tetrachloride, and hydracyanic-acid gas are the fumigants in most common use to-day for treating infested grain. All things considered, carbon disulphide is the most effective fumigant for treating grain in bulk. It is a colorless liquid

which evaporates on exposure to air, forming a vapor that is heavier than air. If applied at the top of a gas-tight bin of grain, the gas will penetrate down through the grain, killing the insects without injury to sound grain.

Carbon disulphide has the great disadvantage that its vapor is highly inflammable and when mixed with certain proportions of air will explode if ignited. Notwithstanding this fire hazard, which must always be taken into consideration, carbon disulphide is in general use on farms for the protection of grain in cribs. For further information on fumigation with carbon disulphide see Farmers' Bulletins 799, 1029, and 1483, published by the United States Department of Agriculture.

Carbon tetrachloride is not very effective as a grain fumigant when used alone, but, owing to its noninflammability it is used extensively in the manufacture of grain fumigants containing small quantities of more powerful but inflammable compounds. Several such mixtures containing carbon tetrachloride, sulphur dioxide, and a small quantity of carbon disulphide are in common use. They are less effective than carbon disulphide alone, but considerably more effective than carbon tetrachloride and, while not entirely free from fire hazard, they are much safer than carbon disulphide.

Hydrocyanic-acid gas generated from calcium cyanide has been used to some extent during the last few years to fumigate grain in large elevator bins. The calcium cyanide, in a finely divided state, is incorporated into the flow of wheat as it enters the bin. Hydrocyanic-acid gas generated from calcium cyanide so distributed through the mass of wheat in the proportion of 25 pounds of the chemical to 1,000 bushels of wheat will, according to the experiments of some, kill all the weevils and does not injure the grain for milling purposes. Grain so treated, however, may temporarily carry an odor, and while this odor ordinarily seems to be of no consequence from the milling and baking standpoint, the grain will be sample graded by Federal inspectors should the odor be considered permanent. This type of fumigation is a highly specialized one, calling for the use of patented equipment.

Chloropicrin is a noninflammable fumigant highly toxic to grain insects. Owing to the fact that it is a tear gas and relatively expensive, its use as a grain fumigant has been limited. The development of better methods of application may greatly increase its use for this purpose.

Ethylene oxide, a newly developed fumigant, shows promise of becoming a valuable fumigant for stored grain. Used in the proportion of 2 pounds for 1,000 cubic feet of space it appears to be effective against grain insects when used in combination with carbon dioxide. The mixture is best suited for use in grain elevators where equipment is available for mixing the material with the grain as the bins are being filled. The ethylene-oxide mixed with carbon dioxide, when used as recommended, is noninflammable and nonexplosive.

Further information regarding the control of grain pests will be found in Farmers' Bulletin 1483, Control of Insect Pests in Stored Grain.

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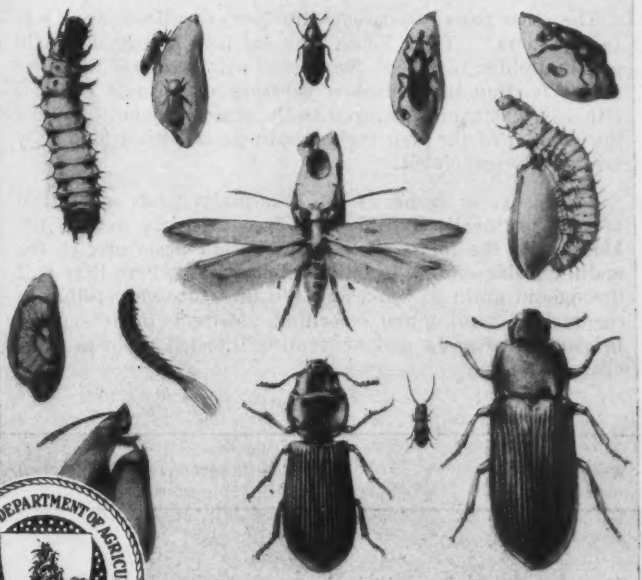
STORED-GRAIN PESTS



UM

MOST of the damage done by insects to grain in storage and shipments is due to four species. These are the granary weevil, the rice or black weevil, the lesser grain borer or Australian weevil, and the Angoumois grain moth. Others of the 46 species or groups of species described in this bulletin can cause great damage to grain if storage conditions are unusually favorable for their increase. Yet if grain in the unbroken kernel remains unaffected by the four insects mentioned, it is not likely, in commercial storage or shipments, to be sufficiently affected by other insects to cause appreciable loss. These four pests live throughout their larval life entirely within the kernel, where they feed unseen, usually unsuspected, and where they can not be reached by the ordinary methods employed by grain men in their grain-cleaning operations known to the trade as moving, fanning, and screening.

The other pests discussed, with few exceptions, are "surface feeders." Their larvæ may eat into kernels of grain and lie hidden there, yet the greater proportion of them are found feeding upon broken surfaces of kernels exposed either by mechanical injuries to the grain in handling or by the feeding of the four major grain pests with which they are usually associated.

The larvæ, or grubs, of the four major pests mentioned are not ordinarily capable of a free existence outside the kernel, but the larvæ of the other grain pests are, in the main, capable of free locomotion, crawling where they will throughout grain in bulk, and are therefore susceptible to removal by fanning and screening. Methods of preventing infestation of grain and of treating infested grain are discussed briefly.

Washington, D. C. Issued April, 1922; revised March, 1931

STORED-GRAIN PESTS

By E. A. Back, *Principal Entomologist in Charge*, and R. T. Cotton, *Senior Entomologist, Division of Stored-Product Insects, Bureau of Entomology*

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POPULAR CLASSIFICATION OF GRAIN PESTS

SINCE THE ESTABLISHMENT of the Federal standards for grain under the provisions of the grain standards act, Federal grain supervisors and federally licensed grain inspectors are required to identify the various species of "live weevils and other insects injurious to stored grain" which may be present in the grain, and uniform names for grain insects should be used. Such uniform terminology will indicate definitely to all interested persons, including shipper, purchaser, and elevator operator, the exact nature of the insect found. Of the four major pests, the granary weevil, the rice or black weevil, and the lesser grain borer may be well called "grain weevils." The fourth of the major pests, the Angoumois grain moth, so destructive to wheat and corn, may be called "grain moth." Other insects likely to be found in any lot of grain may be called simply "beetles," "moths," and "meal worms," for their pres-

ence usually does not indicate a condition likely to affect the trade, provided that after the grain has reached the elevator it is screened and fanned to remove these insects.

The writers have divided the insects discussed in this bulletin into grain weevils, grain borers, grain moths, flour moths, meal worms, grain and flour beetles, psocids, and mites. In some respects this is not a satisfactory grouping, especially for the insects listed as "grain and flour beetles," but it has the advantage of definitely placing the most serious insects troublesome in bulk grain.

GRAIN WEEVILS

Of the four true weevils that attack grain in the United States only two are of primary importance at present, the granary weevil and the rice or black weevil. The broad-nosed grain weevil and the coffee-

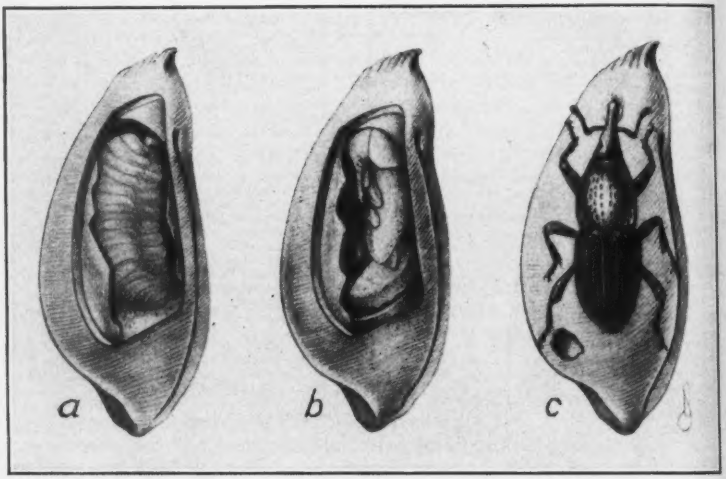

FIGURE 1.—Life stages of the granary weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult. Note hole in kernel made by the adult in order to leave the seed and hole that it is eating into the kernel for the purpose of laying eggs. This weevil closely resembles the rice weevil, but has no papery wings beneath its wing covers and the dotlike punctures on the back behind its head are elongate rather than round

bean weevil are of minor importance except locally. These four weevils have an elongated beak or snout, as shown in the illustrations, though the beak of the coffee-bean weevil is greatly reduced.

GRANARY WEEVIL

The granary weevil, *Sitophilus granarius* L. (fig. 1), is a small, moderately polished, chestnut-brown or blackish beetle with head prolonged into a long slender snout at the end of which are a pair of stout mandibles or jaws. It is not more than three-sixteenths of an inch long, and often smaller. It has no wings under its wing covers and the thorax is well marked with longitudinal punctures,

two characteristics that distinguish it from the closely related rice weevil, with which it is often found associated. The well-grown footless, whitish grub or larva and the pupa are shown at *a* and *b*, respectively, in Figure 1. The granary weevil is one of the oldest known insect pests, is a universal feeder upon grains, and is cosmopolitan, having been carried by commerce to all parts of the world. It prefers a temperate climate and is more frequently found in the Northern States than in the South.

Both adults and larvæ feed voraciously on a great variety of grains. The adult weevils live, on an average, from seven to eight months, the females laying from 50 to 250 eggs each during this period. Before laying her eggs the female bores a small hole in the grain berry with her mandibles. When this has been made she turns about and lays in it an egg which she then covers with a gelatinous fluid that seals the hole. The small, white, fleshy and legless grubs that hatch from the eggs burrow about inside the kernels. When fully grown these transform to the pupal stage and then into the adult weevil form.

In warm weather the granary weevil requires about four weeks to complete its development from the egg to the adult weevil. The developmental period is greatly prolonged by cold weather.

RICE OR BLACK WEEVIL

The rice or black weevil, *Sitophilus oryza* L., is a small snout-beetle which varies considerably in size but rarely measures more than one-eighth of an inch in length. (Figs. 2 and 3.) It varies in color from reddish brown to nearly black and is usually marked on the back with four light reddish or yellowish spots. It closely resembles the granary weevil in form, but it has well-developed wings beneath its wing covers, differs in color and markings, and has the thorax densely pitted with round, instead of longitudinal punctures. Figure 2 gives a good impression of the appearance of the rice weevil and its earlier stages.

This weevil has been known from early times. It is found in all parts of the world where grain is used and is one of the very worst pests in stored grain. It is particularly abundant in warm countries, where it breeds continuously and rapidly destroys all unprotected grain. Throughout the South it causes tremendous losses to corn (figs. 4, 5, 6, and 7) and is the commonest of the serious pests of commercial grain shipments.

The adult weevil lives, on an average, four or five months, each female laying between 300 and 400 eggs during this period. The early stages are almost identical in habit and appearance with those of the granary weevil and need not be further described. The rice weevil is a strong flier. The adults fly from granaries to the fields of grain and there start the infestation that often proves so disastrous after the grain has been harvested. During summer weather the egg, larva, and pupa stages may be passed in as few as 26 days. This period, of course, is greatly prolonged during cool or cold weather. For a further discussion of this pest see Farmers' Bulletin 1029, United States Department of Agriculture.

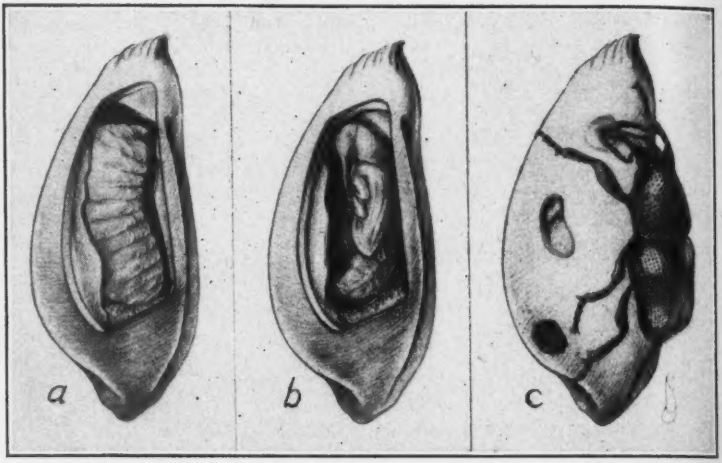

FIGURE 2.—Life stages of the rice or black weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult feeding upon kernel. Note in *c* the hole in lower portion of kernel made by the adult on leaving the seed and at two points higher up shallow holes made by the adult in feeding upon the seed after emergence. The adult weevil is at once distinguished from the granary weevil, shown in Figure 1, by the four light reddish brown or yellow spots on its wing covers, by the possession of wings beneath the wing covers, and by the many rounded punctures on the back behind its head

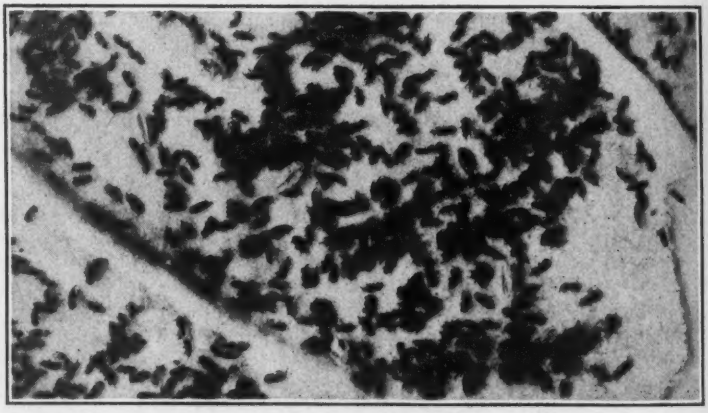

FIGURE 3.—The rice or black weevil: Many adult weevils caught in the mesh of a cloth sack containing pearled barley. Compare their size with that of the barley kernels. Adult weevils when disturbed usually "play possum," but if spread upon a cloth in the sun the live ones will soon show signs of life

FIGURE 4.—Ear of corn with a poor, loose shuck. It is badly infested with rice or black weevils. As the adult weevils feed, they push from the kernels the chewed-up portions, frass, etc., and this material, resembling white dust, collects in large quantities between the kernels and the shuck, or, if the ears are shucked, it falls like powder onto any object below the ear. (Back)

FIGURE 5.—An ear of corn badly damaged by rice or black weevils. This ear has been hit against a table to jar loose the powdery substance, sometimes called the farinaceous material, and so reveals the great damage done by the weevils. The kernels of the ear have been reduced to powder and shell. (Back)

BROAD-NOSED GRAIN WEEVIL

The broad-nosed grain weevil, *Caulophilus latinasus* Say, is a small dark-brown snout beetle slightly less than one-eighth of an inch long. In form and color it resembles the granary weevil somewhat but differs from it and other grain-infesting weevils by having a short, broad snout. (Fig. 8.)

This weevil is occasionally found in Georgia and South Carolina and is widespread in Florida, where it is a serious pest of stored grains. It is unable to breed in dry, hard, uninjured grain, but attacks soft or damaged grain, or grain that has been attacked by other grain insects. It is a strong flier, and, like the rice weevil, flies to the cornfields and infests the grain before it becomes fully hardened.

FIGURE 6.—Kernels of corn taken from badly infested ear corn, showing how the rice or black weevils can thoroughly destroy all parts of the kernel. (Back)

The adult weevils normally live for about five months, and during this time the females lay between 200 and 300 eggs. The small white eggs are usually laid in broken portions of the grain. They hatch in a few days, and the small, white, legless grubs feed on the softer portions of the grain until they become fully grown. They then change to a white pupal form which in a few days transforms to the adult beetle and cuts its way out of the grain. The period from egg to adult in summer is about one month.

COFFEE-BEAN WEEVIL

The coffee-bean weevil, *Araecerus fasciculatus* DeG., is a very active, robust beetle from two-sixteenths to three-sixteenths of an inch long, dark brown in color, clothed with a mottled light and dark-brown pubescence. It may be easily recognized from Figure 9.

This weevil is found in many countries and is extremely abundant in the Southern States, where it breeds in dried fruit, coffee

berries, cornstalks, corn, and the seed and seed pods of an almost endless variety of plants. It is a strong flier and is frequently to be seen in the cornfields of the South on the exposed and damaged ears. It lays its eggs in the soft kernels of corn, and breeding continues after the corn has been harvested and placed in storage. It does not cause much damage to corn in storage, as the corn becomes too hard to be attractive. It may, however, be very abundant locally in corn in Florida during the first three months of storage, and has been reported as completely destroying a sack of kafir seeds in Honolulu. Taking the country at large, the coffee-bean weevil is a very minor grain pest. Figure 10, *a* and *b*, shows the rather characteristic holes cut in the kernels of corn and in corn shucks by the larvæ and emerging adults.

FIGURE 7.—Slip-shuck corn showing holes eaten through the shuck by the rice or black weevil. These holes make passages through which all kinds of grain pests move back and forth to bring about a more speedy destruction of the kernels. (Back)

GRAIN BORERS

Two species of grain borers are now established in the Southern States. The lesser grain borer bids fair to become a very serious pest of grain throughout the South. The larger grain borer has not yet become a factor in commercial shipments of grain.

LESSER GRAIN BORER

The lesser grain borer, *Rhizopertha dominica* Fab., known to many grain dealers more popularly as the "Australian wheat weevil," because of the large supplies of wheat infested by it that reached this country from Australia during the war, is one of the smallest beetles injurious to grain in this country. It is widespread in the Gulf States, and grain samples infested with this beetle are to be found in many large grain centers. It is readily distinguished from other grain pests by its slender cylindrical form and small size. It is

polished dark brown or black in color, with a somewhat roughened surface, about one-eighth of an inch long and one thirty-second of an inch wide. Its head is large, prominent, and bent down under the thorax. The larva, pupa, and adult stages are illustrated in

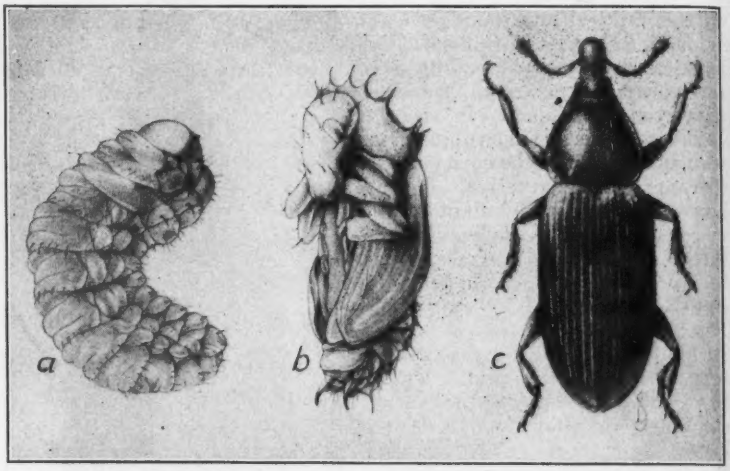

FIGURE 8.—The broad-nosed grain weevil: *a*, Full-grown larva; *b*, pupa; *c*, adult weevil. This weevil is not found in northern-grown grains. It is now present in the southeastern Gulf States. The adult weevil is slightly less than one-eighth of an inch long. It is distinguished from the rice and granary weevils by its much shorter beak

Figure 11. It belongs to a family (Bostrychidae) of beetles that have the head turned down under the thorax and are armed with powerful jaws with which they can cut directly into wood. Originally native to the Tropics the lesser grain borer has spread through commerce to all parts of the world.

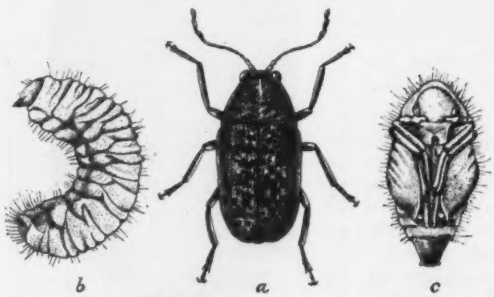

FIGURE 9.—The coffee-bean weevil: *a*, Adult; *b*, well-grown larva; *c*, pupa. The adult is about three-sixteenths of an inch long, of a dark brown color covered with a light and dark brown hairiness. (Chittenden)

Both beetles and larvæ cause serious damage in warm climates, attacking a great variety of grains. The destruction of which they are capable is shown by the wheat kernels of Figure 12, which are literally riddled by the boring adults and their young. The females lay from 300 to 500 eggs each, dropping them singly or in clusters in the loose grain. The eggs hatch in a few days and the small whitish grubs crawl actively about the grain, feeding on the flour produced by the boring

of the beetles, or boring directly into grains that have been slightly damaged. They complete their growth within the grain, transform to white pupæ, and in time change to adult beetles which cut their way out of the grain. The period from egg to adult in summer is said to be about a month.

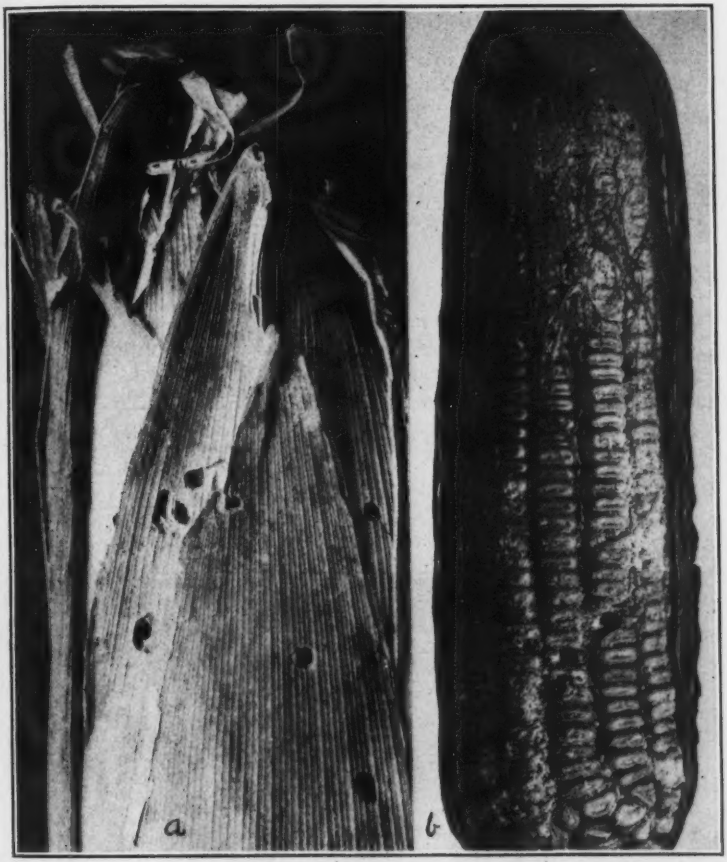

FIGURE 10.—Work of the coffee-bean weevil; *a*, Holes made in corn shucks by the adult weevils eating their way out from the kernels beneath; *b*, two kernels in which larvæ of this insect have developed. Note that a single larva devours a large portion of a single kernel, which is not true of the rice weevil

LARGER GRAIN BORER

The larger grain borer, *Dinoderus truncatus* Horn, is a small, dark brown, elongate-cylindrical beetle about one-sixth of an inch long. As may be seen in Figure 13, it is very similar in appearance to the lesser grain borer, but may be distinguished by its larger size and comparatively smooth, polished surface.

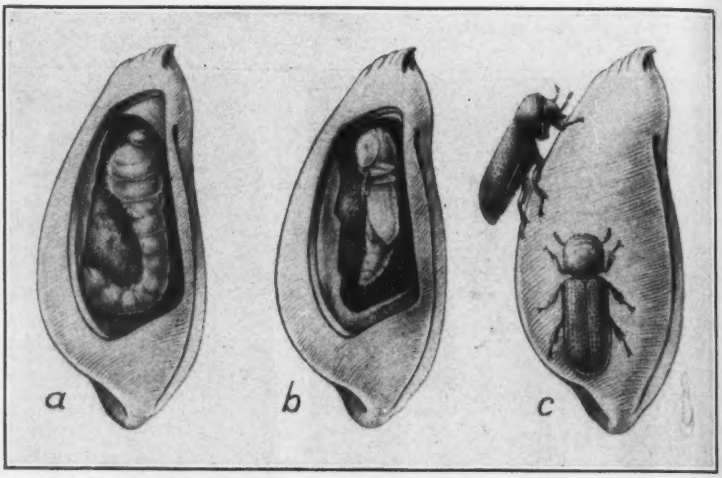

FIGURE 11.—The lesser grain borer in wheat kernels: *a*, The well-grown larva; *b*, the pupa; *c*, two adult weevils. Adult borer is shiny roughened dark brown or black, about one-eighth of an inch long

FIGURE 12.—Kernels of wheat thoroughly riddled and devoured by the boring and feeding of the lesser grain borer and its larva. Such damaged kernels are always surrounded by much powder or flourlike material which the insects have chewed up and pushed out from the kernels

This beetle is a tropical insect not as yet widely distributed in this country. It is occasionally found infesting corn (fig. 14) in the Southern States. Its habits are similar to those of the lesser grain borer. It also has probably acquired its grain-feeding habits rather recently.

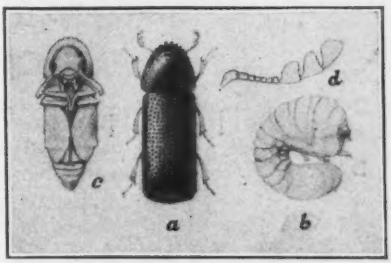

FIGURE 13.—The larger grain borer: a, Adult insect; b, larva; c, pupa; d, antenna of adult. Adult borer is shiny polished dark brown, about one-sixth of an inch long. a, b, c, About six times natural size; d, highly magnified. (Chittenden)

GRAIN MOTHS

The grain moths include only those moths capable of destroying sound, unbroken grain kernels. They are not so abundant as the flour moths, which are principally pests in broken, damaged kernels or milled products.

ANGOUMOIS GRAIN MOTH

The Angoumois grain moth, *Sitotroga cerealella* Oliv., is a small buff or yellowish-brown moth with a wing expanse of about one-half inch. This is the moth most commonly found in infested grain in this country and is not likely to be confused with any other. It attacks all cereal grains, is found in all parts of the world, and is particularly injurious in the South, where it attacks grain both in the field and in storage.

FIGURE 14.—Kernel of corn showing work of adult of larger grain borer. The adult borers tunnel in all directions and reduce kernels to powder and shells. Enlarged. (Chittenden)

Each female moth may lay as many as 400 eggs, which are white when first laid but soon change to a reddish color. The eggs are laid on or near the grain. Upon hatching, the minute white larva or caterpillar bores into a kernel of grain and begins feeding on the contents. When full grown it eats out a channel to the outside of the seed but leaves a thin layer of the seed coat intact. It then changes to a reddish-brown pupa, and later the adult or moth emerges, pushing aside the thin section of seed coat that covers the exit from the channel. The development from egg to adult may be completed in five weeks. Figures 15 and 16 show the successive stages in the development of this insect in a kernel of wheat and of corn from the time the egg is laid until the adult appears. In Figure 17 is shown an ear of corn with the external evidence of heavy attack, and in Figure 18 are shown wheat kernels with the emergence holes of the moth. For a further discussion of this pest see Farmers' Bulletin 1156, The Angoumois Grain Moth.

WOLF MOTH

The wolf moth, *Tinea granella* L., is a small moth about the size of the Angoumois grain moth, creamy white and thickly mottled with brown. The mottled appearance distinguishes it from the Angoumois grain moth. It infests all kinds of grain, both in the

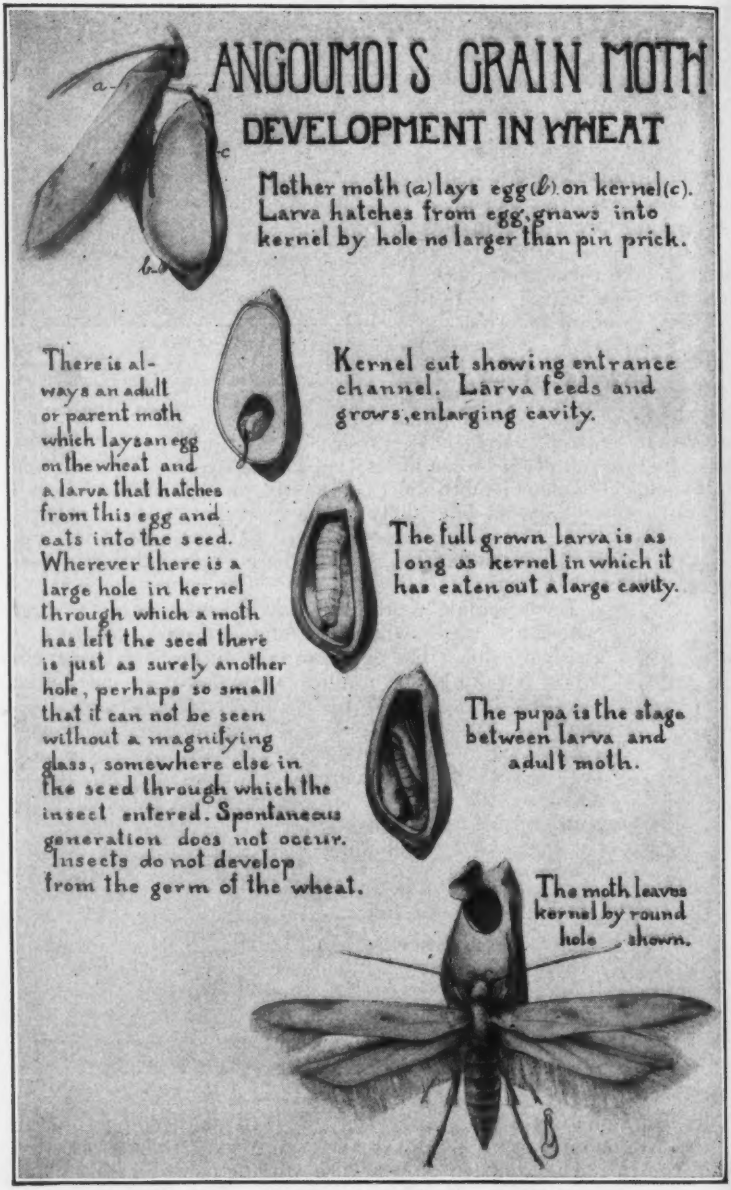
ANGOUMOIS GRAIN MOTH
DEVELOPMENT IN WHEAT
Mother moth (a) lays egg (b) on kernel (c). Larva hatches from egg, gnaws into kernel by hole no larger than pin prick.
Kernel cut showing entrance channel. Larva feeds and grows, enlarging cavity.
The full grown larva is as long as kernel in which it has eaten out a large cavity.
The pupa is the stage between larva and adult moth.
The moth leaves kernel by round hole shown.
There is always an adult or parent moth which lays an egg on the wheat and a larva that hatches from this egg and eats into the seed. Wherever there is a large hole in kernel through which a moth has left the seed there is just as surely another hole, perhaps so small that it can not be seen without a magnifying glass, somewhere else in the seed through which the insect entered. Spontaneous generation does not occur. Insects do not develop from the germ of the wheat.

FIGURE 15.—Life cycle of Angoumois grain moth on wheat. (Back)

field and in storage. The larva feeds on the grain and webs the kernels together.

The wolf moth is distributed throughout the Northern States but is not very abundant and can not be compared with the Angoumois grain moth for destructiveness.

PINK CORN WORM

The pink corn worm, *Pyroderces rileyi* Wals., is the larva or caterpillar of a small moth. (Fig. 19.) It is about five-sixteenths of an inch long when full grown; pink in color, with head and thoracic shield pale brown. Figure 20 gives a good idea of its appearance. The moth which develops from this worm or larva is smaller than the Angoumois grain moth, with a wing expanse of slightly less than half an inch. The forewings are banded and mottled with yellow,

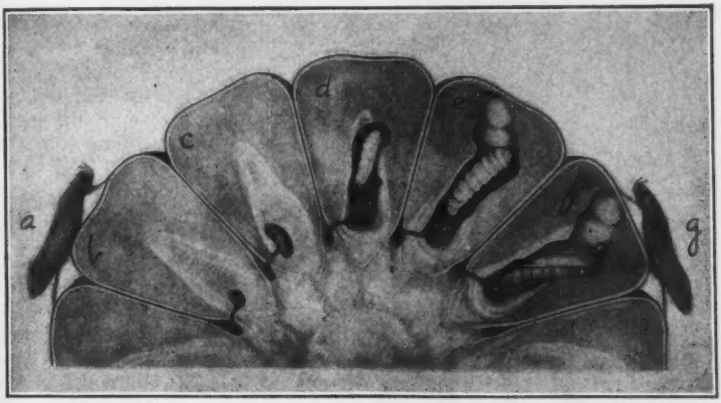

FIGURE 16.—Cross section of ear of corn showing development of Angoumois grain moth in corn. The newly hatched larva crawls down to the germ end of the corn and begins feeding upon the soft germ. As it grows older and stronger it eats out into the firmer portion of the kernel and finally, in most instances, eats to the outer end. (Back)

reddish brown, and black, as shown by Figure 19. The pale grayish hindwings are very slender and are edged with long fringes. The pupa is shown in Figure 21.

This insect is common in the South, where it causes considerable injury to corn, both in the field and in storage. Infestation begins in the field and is continued after the corn is placed in storage. The very characteristic injury is shown in Figures 22 and 23. The large amount of frass that is loosely webbed together and fills the interstices between the kernels or is crowded into the cavities of kernels that have been eaten out is a reliable indication of the presence of this pest. The pearly white eggs are laid singly or occasionally in twos or threes. The pinkish larvæ feed on the seed, husk, and cob with equal relish. Though capable of serious injury to corn, in particular as it comes to maturity in the field, and while in the cribs on southern farms, the pink corn worm is seldom a serious pest of commercial shipments.

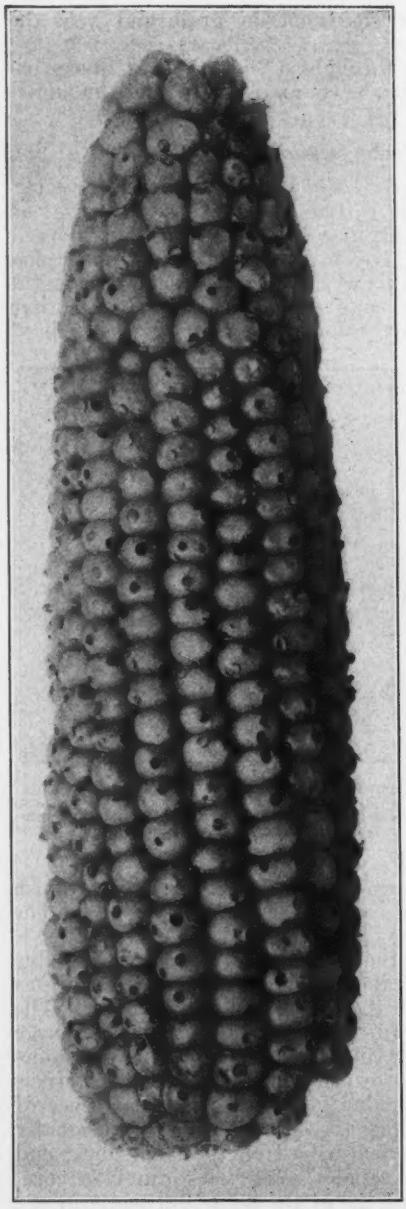

FIGURE 17.—Ear of pop corn showing heavy infestation by the Angoumois grain moth. Note that certain of the kernels have three emergence holes, and that many have served as food for two larvæ. The development of a single insect in a kernel causes a loss of from 13 to 24 per cent in weight

RICE MOTHS

The rice moth, *Corcyra cephalonica* Staint., has a wing expanse of about half an inch and is of a pale grayish-brown or tawny color. Its characteristic appearance is shown in. Figure 24. The larva (fig. 25) resembles somewhat that of the Indian meal moth, being when full grown about half an inch long and varying in color from white to a dirty, slightly bluish gray with occasional tints of green. Damage by the pest, as in the case of all moth pests, is done by the larvæ, which feed upon rice, cocoa, chocolate, ship biscuits, etc. The larvæ produce a dense webbing as they become well grown. When feeding upon grains they spin dense silken tubes, webbing the grain kernels into the walls of the tubes. The pupa is shown in Figure 26. The rice moth is seldom found in this country and has not become very widely disseminated.

FLOUR MOTHS

Among the flour moths are some of the commonest and most serious pests of grain products. They are designated as flour moths not because they feed entirely upon flour or milled products, but because they seldom attack sound grain kernels. They prefer broken grains, grains injured by major grain pests, and more especially cereal milled products such as flour, breakfast foods, meals, etc. All three

of the flour moths are commonly found in grain warehouses, but the Indian meal moth and the meal snout moth are probably the most

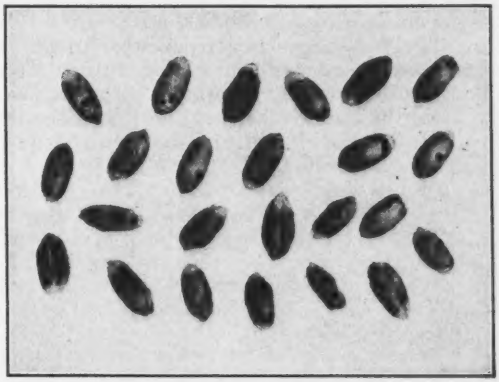

FIGURE 18.—Kernels of wheat showing the small round emergence holes that prove that the Angoumois grain moth has developed in the seed, thus reducing the weight somewhat over 50 per cent. (Back)

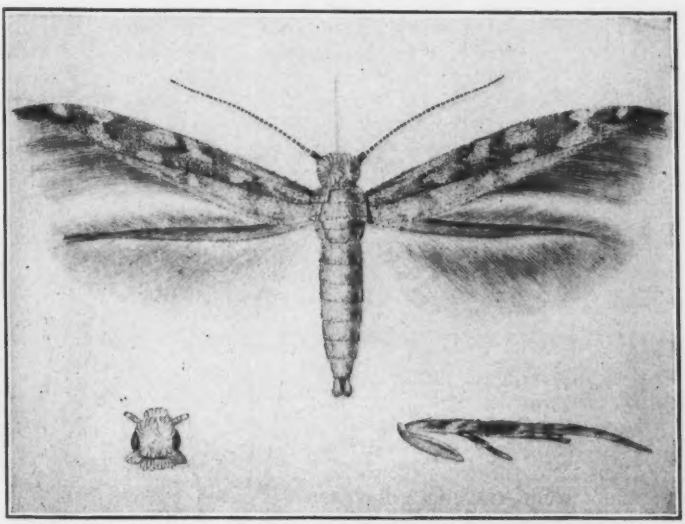

FIGURE 19.—The pink corn worm: Moth, much enlarged; head and leg more enlarged. The moth has a wing spread of a little less than half an inch. (Chittenden)

frequently reported. These two moths may, under specially favorable conditions, become established in whole grain and other seeds and cause injury especially by eating out the germ.

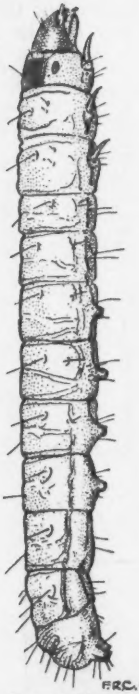

FIGURE 20.—The pink corn worm: Full-grown larva, side view, greatly enlarged. When full grown the larva is pink and about five-sixteenths of an inch long. (Chittenden.)

INDIAN MEAL MOTH

The Indian meal moth, *Plodia interpunctella* Hbn., is a rather handsome moth with a wing expanse of nearly three-fourths of an inch. It is easily distinguished from other grain pests by the peculiar marking of its forewings. These are reddish brown with a coppery luster on the outer two-thirds, but whitish gray on the inner or body end. Moths and larvæ are shown in Figure 27. The female moths lay from 300 to 400 eggs, singly or in groups, on food material. The eggs hatch within a few days into small whitish larvæ or caterpillars. These larvæ feed upon grains, grain products, dried fruits, nuts, and a rather wide variety of foodstuffs. When full grown, the larvæ are about half an inch long, dirty white in color, varying sometimes to greenish and pinkish hues. A full-grown larva is shown in Figure 28, clinging to a kernel of wheat. This larva spins a silken cocoon and transforms to a light-brown pupa, from which the parent moth later emerges. The Indian meal moth may pass through its egg, larva, and pupa stages in about four weeks during warm weather.

The larva of the Indian meal moth spins a web as it becomes full grown, and leaves behind a silken thread wherever it crawls. When sacks of cracked corn, meal, or corn in the ear that has been previously injured by other pests become heavily infested, this webbing often is sufficiently abundant to attract attention. The loosely clinging web shown on the ear of corn in Figure 29 is characteristic of this pest.

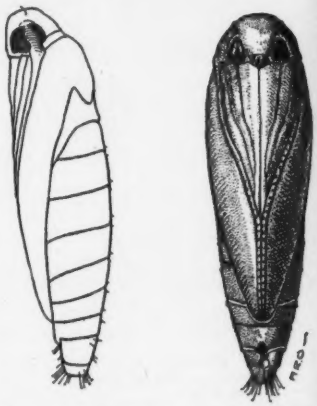

FIGURE 21.—The pink corn worm: Pupa, ventral view at right, lateral view at left. Enlarged. (Chittenden)

MEDITERRANEAN FLOUR MOTH

The Mediterranean flour moth, *Ephestia kuehniella* Zell., has a wing spread of slightly less than 1 inch. Its hindwings are a dirty white, but its forewings, which alone show when the moth is not flying, are a pale leaden gray with transverse wavy black markings. (Fig. 30.)

The Mediterranean flour moth is a native of Europe. Its first discovery in the United States was in

California in 1892. Since then it has spread to practically all the States and is recognized as the most serious pest of flour mills, owing to the silken threads which the larvæ spin wherever they crawl. These webs mat the flour or meal together and eventually clog machinery so that mills have to shut down for a thorough cleaning and treatment. Although preferring flour and meal, the Mediterranean flour moth attacks grain, bran, and cereal products and is commonly found in storehouses and granaries.

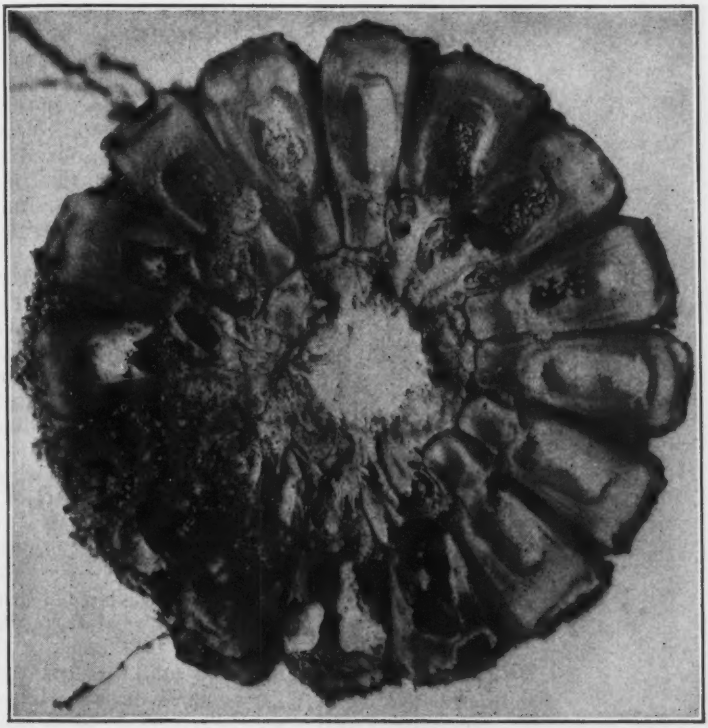

FIGURE 22.—Ear of corn cut to show characteristic feeding and destruction by pink corn-worm larvæ. Note that the larvæ eat from one kernel to another, often severing the kernels from the cob. The larvæ sometimes eat into the cob, and there transform to the pupa stage. The pupæ are about one-third as long as the kernels shown

The female moth lays small white eggs in accumulations of flour, meal, or waste grain. From the eggs the small larvæ hatch in a few days. When full grown, these are about half an inch long and are of a whitish or pinkish color with a few small black spots on the body. The full-grown larva spins a silken cocoon in which the insect transforms to a reddish-brown pupa. Later the parent moth emerges from the pupa. During warm weather, the Mediterranean flour moth requires about nine weeks to pass through its egg, larva, and pupa stages.

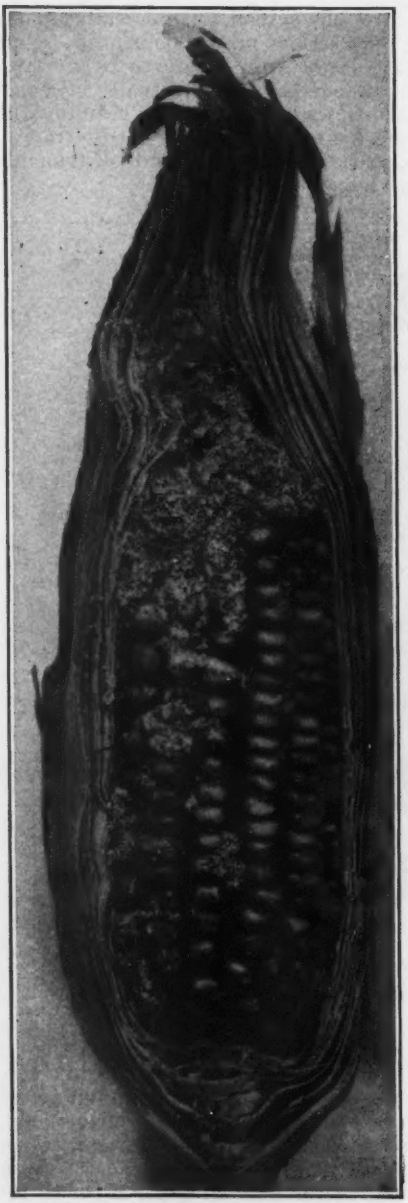

FIGURE 23.—Ear of corn with portion of shuck removed to show surface feeding by larvæ of the pink corn worm. Often many kernels drop from the ear when the shucks are removed because of the feeding of the pink corn worm larvæ

MEAL SNOUT MOTH

The meal snout moth *Pyralis farinalis* L., is brownish in color, somewhat larger than the Indian meal moth, though varying in size, usually having a wing spread of about 1 inch. Its forewings are marked in a characteristic pattern indicated in Figures 31 and 32; they are light brown with dark-brown patches at base and tip and each with two wavy transverse white lines. The meal snout moth is widely distributed and a general feeder in the larva stage upon cereals of all kinds, both ground and in the berry. It sometimes attracts much attention because of its capacity to web up and bind together seeds of various kinds. The larvæ are whitish and attain a length when full grown of about 1 inch. The two larger larvæ of Figure 31 indicate the normal shape and show the contrast between the black of the head and the first body segment and the white of the remainder of the body. Often the body of the larva is tinged with orange toward each end. The larvæ spin peculiar tubes of silk and particles of the food material. They rest in these tubes, which are very tough, and feed from the openings at the ends. When full grown the larvæ

leave the tubes, spin silken cocoons, often covered with food particles, and transform to the pupæ from which later emerge the adult moths. The meal snout moth may require only eight weeks to pass through the egg, larva, and pupa stages.

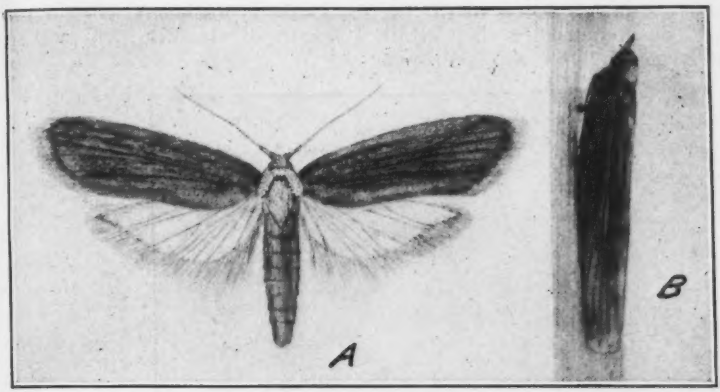

FIGURE 24.—The rice moth: *a*, Mature moth, dorsal view, with wings spread; *b*, side view of same moth with wings folded about body. The moth is of a grayish brown of tawny color, with a wing spread of about half an inch. Much enlarged. (Chittenden)

The meal snout moth is primarily a pest of seeds that are held for some time in cool and damp localities. Outbreaks that have come to the attention of the writers have always been centered in grain that

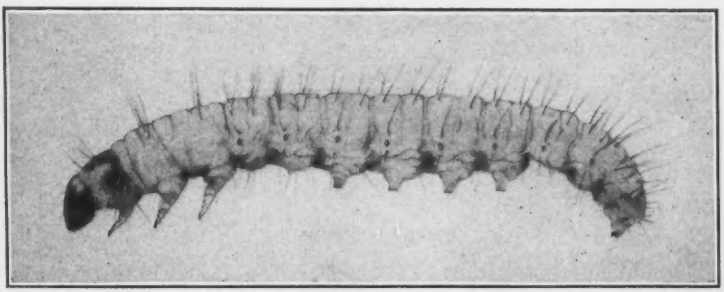

FIGURE 25.—Full-grown larva of the rice moth. The full-grown larva is about one-half inch long, and is of a whitish or bluish gray color. Much enlarged. (Chittenden)

was harvested during rainy weather or so stored that the moisture content was unusually high. Attempts to rear the moth in dry, warm laboratories have failed. The larvæ cut through burlap sacking and can damage sacks greatly when heavy infestations develop in sacked material. Figure 33 shows the characteristic webbing together of infested seeds—in this instance navy beans—and Figure

32 shows the tendency for larvæ to spin their whitish silken cocoons on the outside of grain sacks where the sacks touch each other.

MEAL WORMS

There are two species of meal worms in the United States. The adults are the largest of the beetles found in grain and their larvæ are conspicuous, for they attain a length of about 1 inch and are as large around as an earthworm.

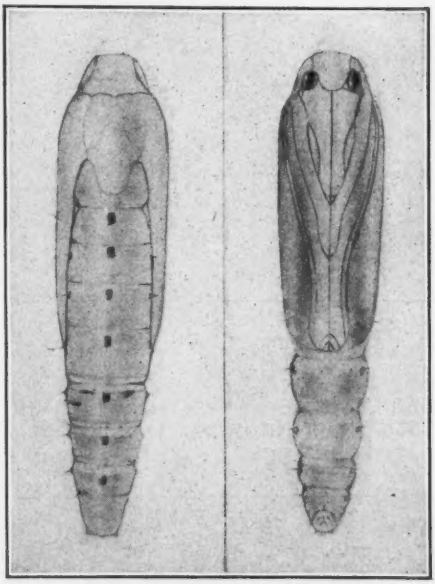

FIGURE 26.—Pupa of the rice moth: At left, dorsal view; at right, ventral view. The pupa is found in a dense tough cocoon into the walls of which have been spun particles of the food. The cocoons of the Indian meal moth, on the other hand, are very loosely constructed. Much enlarged. (Chittenden)

YELLOW MEAL WORM

The adult of the yellow meal worm is a polished dark-brown or black beetle, somewhat more than half an inch long, with its thorax finely punctured and with its wing covers longitudinally striated or grooved. (Fig. 34, right.) The females lay bean-shaped white eggs covered with a sticky secretion that causes the flour, meal, or grain waste in which they are placed to adhere to them. The eggs hatch in about two weeks into slender white larvæ, which soon turn yellow and assume the form shown in Figure 34. When full grown, the larvæ are about an inch long and yellowish, shading to yellowish brown toward each end and at the articulation of each segment. The pupa into which the larva transforms before becoming an adult beetle is shown in Figure 34.

FIGURE 27.—The Indian meal moth: Tip of ear of corn showing, *a*, three moths with their characteristic light and dark markings, and *b*, two well-grown larvæ. The adult moth is distinguished from all other grain-infesting moths by having the outer two-thirds of its wings brownish and the inner third whitish gray. It has a wing spread of about three-fourths of an inch

The yellow meal worm, *Tenebrio molitor* L., is widespread over the world and is frequently found in stored grains. It belongs to a family of beetles (Tenebrionidae) known as the darkling beetles because of their preference for dark places. The adults fly only at night. During daylight they conceal themselves, with the larvæ, beneath sacks of grain, under grain boxes, or beneath grain and other food. There is but one generation each year. The adults begin to appear in the latitude of Washington, D. C., in the latter part of May and early in June and may be found until late in August. The female beetles are quite prolific and may lay as many as 500 eggs each. The larvæ become full grown in about three months, but instead of transforming then to the adult stage they continue feeding

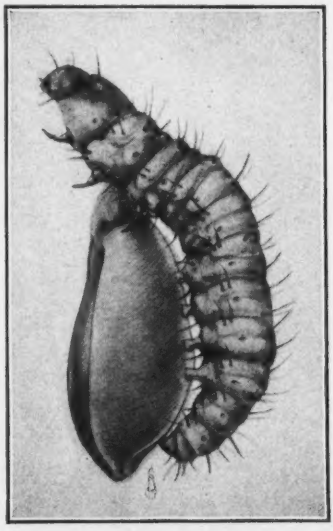

FIGURE 28.—Well-grown larva of the Indian meal moth, crawling on kernel of wheat. These worms are white or greenish in color and frequently eat out the germ end of wheat. They attain a length of about half an inch

and molting until cold weather and then hibernate as larvæ. In late spring or early summer of the following season they transform to the pupal stage, in which stage the insect passes about two weeks. Because the yellow meal worm has but one generation each year, and is entirely an external feeder upon grains, it need not be feared as a serious pest. Screening and fanning will remove it easily from grain shipments. The well-grown larvæ, however, can do serious injury to whole grains under certain conditions when grain is held for long periods without being moved.

DARK MEAL WORM

The dark meal worm, *Tenebrio obscurus* Fab., as may be seen by the larva, pupa, and adult shown in Figure 35, is very similar in

FIGURE 29.—Ear of corn showing the loose webbing characteristic of the Indian meal moth larvæ. This moth rarely attacks sound grain, but, as is here shown, frequently attacks grains already injured by other grain pests. Such webbing as is here shown develops only when corn or other grains are left unmoved for some time

form, size, and color to the yellow meal worm, to which it is closely related. The adult beetle differs, however, in being dull pitchy black, in contrast to the shiny or polished dark brown or black of

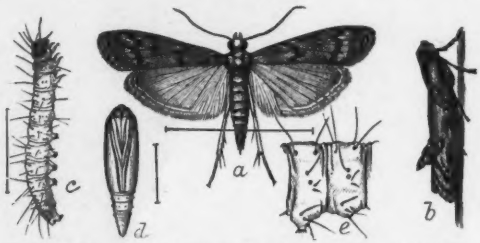

FIGURE 30.—The Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa (enlarged); *e*, abdominal joint of larva (more enlarged). The adult moth, with a wing expanse of a trifle less than 1 inch, is leaden gray in color, marked with transverse wavy black markings. The full-grown larva is whitish or pinkish in color, with small black spots, and is about one-half an inch long. (Chittenden)

the yellow meal worm. Its larva so closely resembles the larva of the yellow meal worm that it can be distinguished most easily by its much darker color.

The two species of meal worms are often found associated since they have similar feeding habits. The overwintering larvæ of the

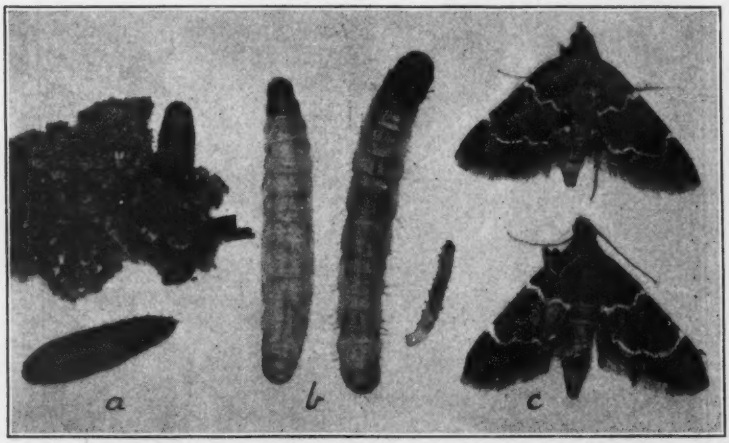

FIGURE 31.—The meal snout moth: *a*, Pupa and, above, webbed mass of grain showing portion of pupa protruding; *b*, two well-known larvæ with a smaller larva at right; *c*, two adult moths. Magnified about one and one-half times. The markings on the forewings easily distinguish this insect from other grain pests

dark meal worm begin to pupate earlier in the season than the yellow meal worms, and the adult beetles emerge during April and May in the vicinity of Washington.

FIGURE 32.—Inside of a grain sack that was filled with infested vetch seed. Note vetch seeds sticking to side of bag as a result of the webs of the larvæ of the meal snout moth, the numerous whitish cocoons with dark pupæ within, and, in the center, one adult moth. Natural size

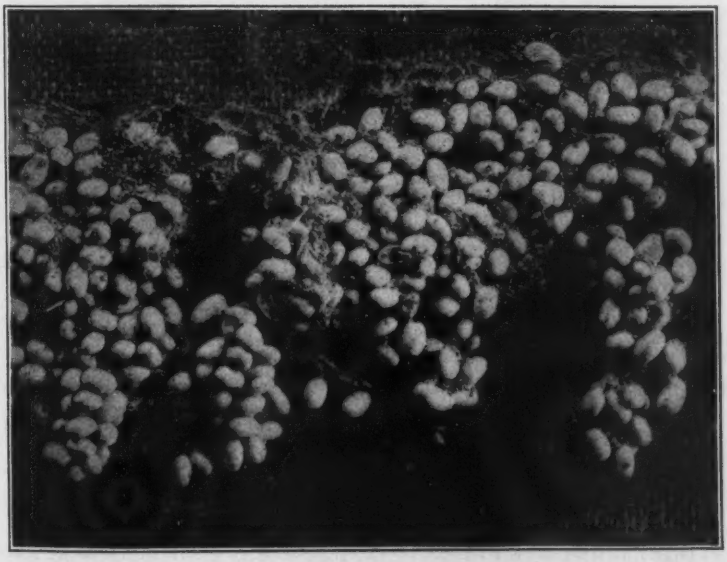

FIGURE 33.—Navy beans webbed together by larvæ of the meal snout moth, and adhering to sack. The larvæ often cut sacks so seeds fall out and lodge where sacks touch each other. In these places the seeds are usually more heavily infested

GRAIN AND FLOUR BEETLES

CADELLE

The cadelle, *Tenebroides mauritanicus* L., is an elongate, oblong, flattened, black or blackish beetle about one-third of an inch long. It resembles the meal worms in appearance, but is much smaller and the thorax and abdomen are loosely joined. (Fig. 36.)

The larva of the cadelle is one of the largest of the grain-infesting insects and is easily recognized. It is about three-quarters of an inch long, fleshy, with the abdomen terminating in two dark horny points.

FIGURE 34.—The yellow meal worm. Four well-grown larvæ, two pupæ, and the black adult beetle, with five kernels of wheat to indicate relative size. The larvæ when full grown are about 1 inch long and yellowish. The adult beetles are shiny black and slightly more than half an inch long

The larva is a dirty or chalk white, with head, thoracic shield, and the two horny points at end of body black, as shown in Figure 37.

This insect is widespread over the world and is frequently found in mills, granaries, and storehouses, where it infests flour, meal, grain, etc. Both larva and adult feed on grain and have the destructive habit of going from kernel to kernel and devouring the embryo. The cadelle often becomes well established in ear corn (fig. 38) that has first been injured by the Angoumois grain moth or by the weevils. The long slits in corn kernels shown in Figure 38 are char-

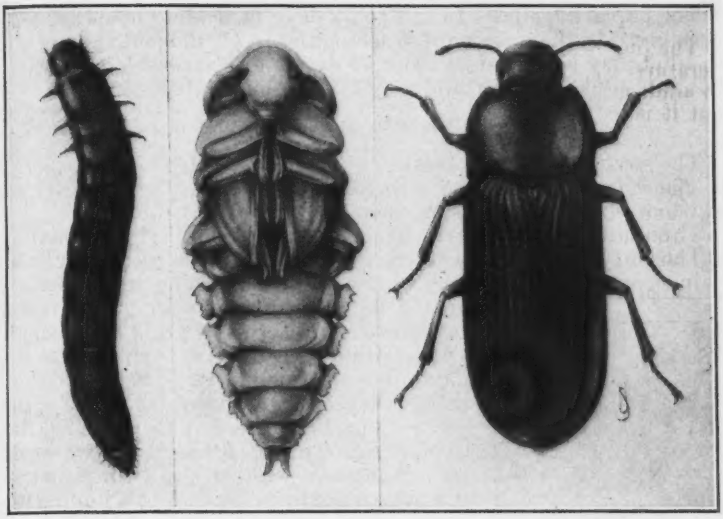

FIGURE 35.—The dark meal worm: *a*, Full-grown larva; *b*, pupa; *c*, adult beetle. Distinguished from the yellow meal worm by the dark brown color of the larva and the dull, not shiny appearance of the adult beetle. For true relative size of the larva, pupa, and adult compare with Figure 34

acteristic of cadelle infestation. The cadelle is one of the longest lived of the insects that attack stored grain; many of the adults live for more than a year, and some of them for nearly two years. The female beetles oviposit during the greater part of their lives and under favorable conditions will lay about 1,000 eggs each.

The white eggs are laid in clusters in the food material and hatch in from 7 to 10 days in warm weather. The larvæ complete their growth in from 2 to 14 months, then seek some secluded place in which to transform to the pupal stage (fig. 39), frequently boring into the timbers of the bin or other receptacle that holds the infested material. Both larvæ and adults can live for considerable periods without food, frequently remaining hidden in the woodwork of the bins for a long time after the grain has been removed. When new grain is put into such a bin it becomes infested in a surprisingly short time.

FIGURE 36.—The cadelle: Adult beetle. The cadelle is a flattened, black beetle about one-third of an inch long

The pupal stage lasts from 8 to 25 days, depending upon the temperature. In the vicinity of Washington, D. C., the period from egg to adult may be passed in about 70 days under favorable conditions, but it is usually longer and may take as long as 400 days.

SAW-TOOTHED GRAIN BEETLE

The saw-toothed grain beetle, *Oryzaephilus surinamensis* L., gains its name from the peculiar structure of the thorax, which bears six saw-tooth-like projections on each side. (Fig. 40.)

The adults live, on an average, from 6 to 10 months, but some individuals may live as long as three years. The female beetles lay from 100 to 200 eggs, dropping them loosely among the foodstuff or tucking them away in a crevice in a kernel of grain. The small, slender, white eggs hatch in from three to five days. The emerging larvæ do not spend their lives within a single grain, but crawl about actively, feeding here and there. They become full grown (fig. 40) in about two weeks during summer weather and then construct delicate cocoonlike coverings by joining together small grains or fragments of foodstuffs with a sticky secretion. Within this pupal cell the larva changes to the pupal stage, which last about a week. Development from egg to adult may take place in from three to four weeks in summer.

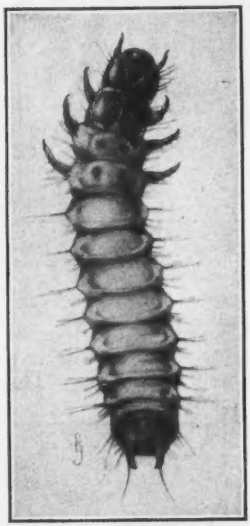

FIGURE 37.—The cadelle: Larva. Commonly found crawling among grain kernels. It may appear glistening white or dull and powdered according to the material in which it is crawling. When full grown it is about three-fourths of an inch long

MERCHANT GRAIN BEETLE

The merchant grain beetle, *Oryzaephilus mercator* Fauv., closely resembles the preceding species and has similar food habits. It differs in appearance from the saw-toothed grain beetle (fig. 41) chiefly by the much narrower, more sharply projecting temples (fig. 42, *a*) and in having the head and trochanters (second joint from the base in the leg) of the male unarmed.

It is apparently not so widely distributed in this country as the saw-toothed grain beetle, although the close resemblance between the two species may many times have resulted in the crediting of infestations of the merchant grain beetle to the saw-toothed grain beetle.

SQUARE-NECKED GRAIN BEETLE

The square-necked grain beetle, *Silvanus gemellatus* Duv., is closely related to the saw-toothed grain beetle, which it greatly resembles in form, size, and color. It is a flattened, oblong, polished, reddish-brown beetle about one-tenth of an inch long. It differs from the saw-toothed grain beetle by having the thorax almost square in shape and lacking the saw-toothlike projections. (Fig. 43.)

This beetle is chiefly abundant in the South, where it is found in great numbers outdoors infesting the seed pods of a great variety of plants. It is one of the most common beetles in stored corn in the South and in the cornfields is always to be found on damaged or exposed ears. The immature stages closely resemble those of the preceding species both in form and in habit. The larvæ have the bad habit of devouring the germ of the seed in which they breed. They can develop from egg to adult in about three weeks.

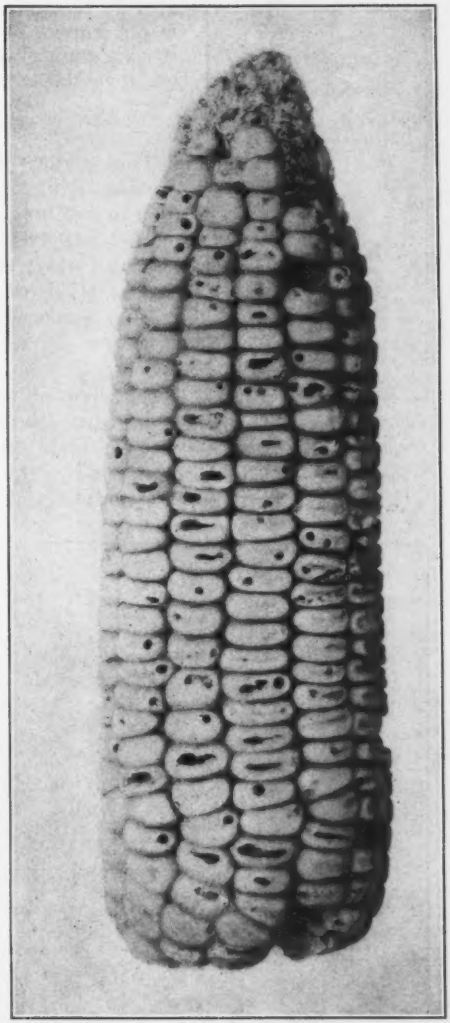

FIGURE 38.—Ear of corn infested by the Angoumois grain moth (round holes in kernels) and the cadelle. The elongated slits in the kernels are characteristic of cadelle feeding and emergence. Only ear corn stored for several years will develop this evidence of cadelle attack

FOREIGN GRAIN BEETLE

The foreign grain beetle *Cathartus advena* Waltl., is a small reddish-brown beetle somewhat similar in appearance to the preceding species, to which it is closely related. It differs from it by being smaller and more robust. (Fig. 44.) Although of world-wide distribution, it is of little consequence as an enemy of stored grains. It is attracted to damp and moldy grains and feeds on the molds developing in such grains. It is rarely found in clean grain.

MEXICAN GRAIN BEETLE

The Mexican grain beetle, *Pharaxonotha kirschi*, Reitt., is a highly polished, deep-brown beetle about three-sixteenths of an inch long. While resembling somewhat the confused flour beetle in general appearance, it can be readily distinguished by its more polished surface and by its longer antennæ. (Fig. 45.)

FIGURE 39.—The cadelle: Pupa, much enlarged. The pupa is seldom seen, as this stage of the cadelle's life cycle is spent in a cell made in an inaccessible place

This insect is common in Mexico, where it breeds in grain and grain products. It was found in this country in grain exhibits at the World's Columbian Exposition, but is not known to be permanently established in this country as yet. It may be found in grain in the extreme South.

SIAMESE GRAIN BEETLE

The Siamese grain beetle, *Lophocateres pusillus* Klug, is an elongate, flattened, reddish-brown beetle slightly less than an eighth of an inch long, characterized by the much flattened margins of the thorax and wing covers. (Fig. 46.)

First appearing in exhibits of rice and cereals from Siam, Liberia, and Ceylon at the World's Columbian Exposition, it has since been reported as injurious to stored grain and grain products in South Carolina and Texas. It is likely to be found in seaport towns and in the Southern States, but as yet it is not abundant or widespread.

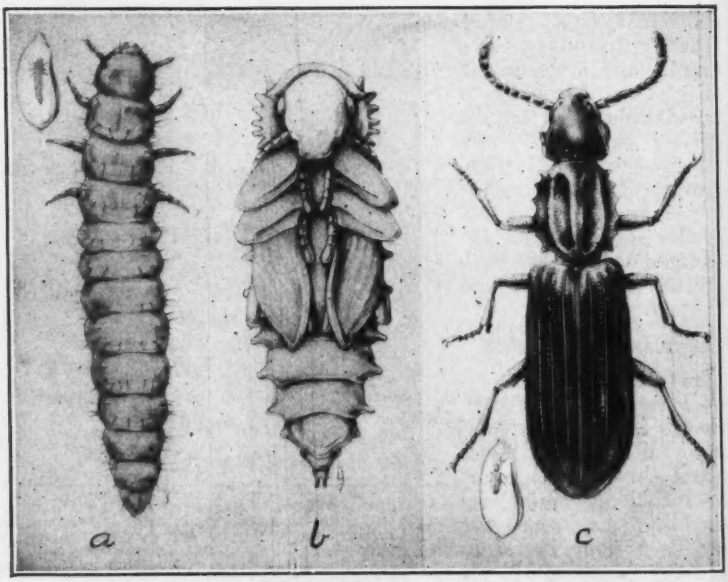

FIGURE 40.—The saw-toothed grain beetle: *a*, Well-grown larva, with kernel of wheat to show its relative size; *b*, pupa; *c*, adult beetle with kernel of wheat to show its relative size. The adult beetle, about one-tenth of an inch in length, can be easily recognized by the six toothlike projections on each side of the thorax

FLAT GRAIN BEETLE

The flat grain beetle, *Cryptolestes pusillus* Schön., is a small flattened, oblong, reddish-brown beetle about one-sixteenth of an inch long, with elongate antennæ somewhat longer than half the

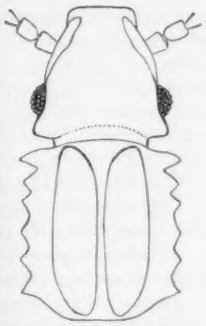

FIGURE 41.—Head and thorax of saw-toothed grain beetle

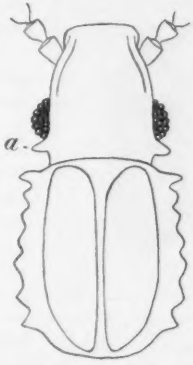

FIGURE 42.—Head and thorax of merchant grain beetle. Note the narrow, sharply projecting temples at *a*

FIGURE 43.—The square-necked grain beetle. (Chittenden)

FIGURE 44.—The foreign grain beetle. (Chittenden)

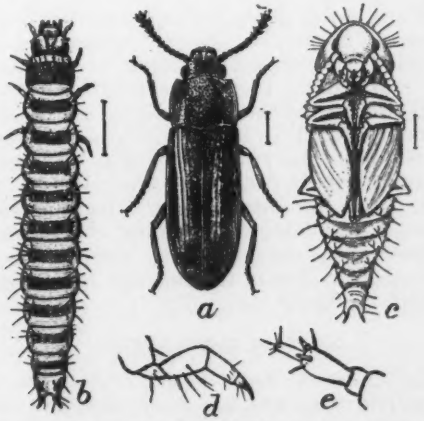

FIGURE 45.—The Mexican grain beetle: *a*, Beetle; *b*, larva; *c*, pupa; *d*, leg of larva; *e*, antenna of larva. *a*, *b*, *c*, Much enlarged; *d*, *e*, more enlarged

length of its body. (Fig. 47.) It is readily distinguished because it is the smallest beetle commonly found in stored grain in this country. It is cosmopolitan in distribution, is very generally found in stored corn in the South, and is often screened from wheat shipments. It is not a primary pest of stored grain, and the adult is

apparently unable to survive in sound, uninjured grain. It follows up the attack of the more vigorous grain pests and is frequently found associated with the rice weevil in enormous numbers. It is a scavenger by nature and often infests grain and meal that is out of condition.

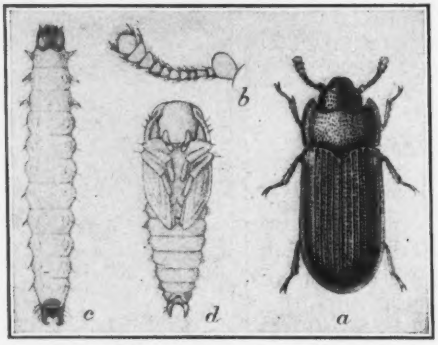

FIGURE 46.—The Siamese grain beetle. *a*, Beetle; *b*, antenna of same; *c*, larva; *d*, pupa. *a*, *c*, *d*, About 10 times natural size; *b*, greatly enlarged

The small white eggs are placed in crevices in the grain or dropped loosely in farinaceous material. The larvæ are particularly fond of the germ in wheat, and in infested grain many kernels will be found uninjured except for the removal of the germ. The larvæ also feed on dead insects. When fully grown the larvæ form cocoons of a gelatinous substance to which food particles adhere. They transform to the pupal stage in these cocoons and later emerge as adults.

RUST-RED GRAIN BEETLE

The rust-red grain beetle, *Cryptolestes ferruginous* Steph., is closely related to the preceding species and is similar to it in form, size, and habit. It is more resistant to cold weather than the flat grain beetle and is more commonly found in stored grain in the Northern States. The two species may be readily distinguished by the fact that in the flat grain beetle the antenna of the male is about as long as the body and is about twice as long as that of the female beetle, whereas in the rust-red grain beetle the antenna of the male is short. (Fig. 48.)

FIGURE 47.—Adult of the flat grain beetle, showing characteristic long antennæ. Not more than one-sixteenth of an inch long. This beetle is one of the very smallest found in grain shipments

CONFUSED FLOUR BEETLE

The confused flour beetle, *Tribolium confusum* Duv. (fig. 49), is a shiny, reddish-brown beetle about one-seventh of an inch long, flattened and oval in form, with head and upper parts of thorax densely covered with minute punctures and with wing covers ridged lengthwise and sparsely punctured between the ridges. It is generally distributed over the world and is very abundant in all parts of this country. It is known as one of the flour beetles owing to its frequent occurrence in flour. It is a general feeder on starchy foods and is probably the worst insect pest of prepared cereal foods. It is

constantly found in granaries, mills, and storehouses, and grain shipments.

The minute white eggs of this beetle are laid in the cracks and crevices of bins, barrels, boxes, or other containers of the foodstuffs attacked by this insect. They are covered with a sticky secretion, so that they become covered with flour, meal, etc., and readily adhere to the sides of sacks, boxes, and other containers so fresh material placed in them is rapidly infested. The eggs hatch into small worm-like larvæ, slender, cylindrical, and wiry in appearance. When fully grown they are about three-sixteenths of an inch long, and in color are white, tinged with yellowish. These larvæ feed on flour or other material such as grain dust and the broken surfaces of grain kernels. When full grown they transform to small naked pupæ. At first white, the pupæ gradually change to yellow and then brown, and shortly afterwards transform to beetles. The period from egg to adult in summer is about four weeks under most favorable weather conditions, though the life cycle is greatly prolonged by cold weather, as is true of all grain pests.

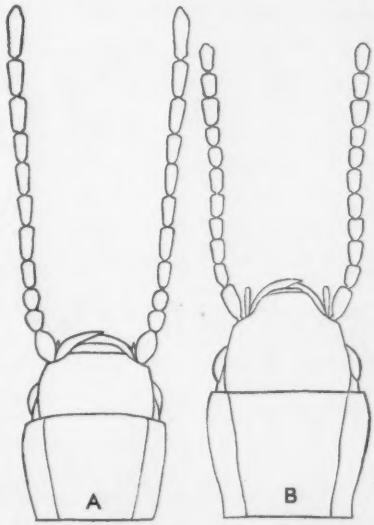

FIGURE 48.—Thorax, head, and antennæ of male beetles, showing the relative length of the antennæ as compared with those parts of the body in—*a*, the flat grain beetle; *b*, the rust-red grain beetle

RUST-RED FLOUR BEETLE

The rust-red flour beetle, *Tribolium ferrugineum* Fab., is almost identical in appearance with the preceding species, to which it is closely related. It can be distinguished from the confused flour beetle only with the aid of a magnifying glass. The segments of the antennæ of the confused flour beetle increase in size gradually from the base to the tip, while in the rust-red flour beetle the last few segments of the antennæ are abruptly much larger than the preceding ones, giving the antennæ the appearance of being suddenly enlarged at the tip. In addition, the margins of the head of the confused flour beetle are expanded and notched at the eyes, while the margins of the head of this species are nearly continuous at the eyes. The differences between the two species are clearly shown in Figure 49, *e* and *f*.

This insect is similar to the confused flour beetle in feeding and breeding habits, and it is impossible to distinguish between the early stages of the two insects. Although cosmopolitan in distribution, it is found more commonly in the South, where it causes very serious damage to grain products. In addition to the actual damage caused by its feeding activities, serious losses are caused by the nauseous

smell and taste that it imparts to the material it infests. Like the confused flour beetle, the rust-red flour beetle is primarily a pest of milled products, and while present in grain shipments it confines its attack in these to grain dust and the surface of broken grains, hence is not a primary pest of commercial shipments.

LONG-HEADED FLOUR BEETLE

The long-headed flour beetle,[1] *Latheticus oryzae* Waterh., is a slender, flattened beetle, slightly less than an eighth of an inch long, somewhat similar in form to the confused flour beetle but pale yellow and further differentiated by the peculiarly shaped antennæ shown in Figure 50 and by the minute canthus behind each eye. It has been reported from most parts of the world infesting wheat, rice, corn, barley, rye, flour, etc. It was first recognized in this country

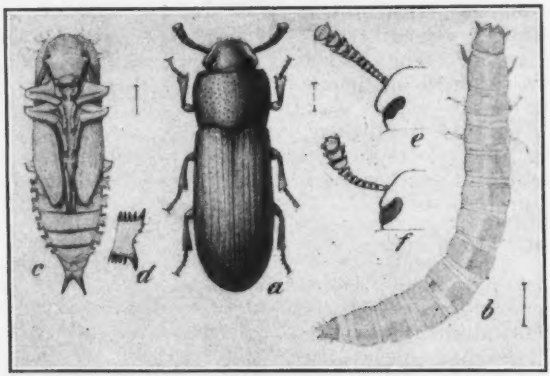

FIGURE 49.—The confused flour beetle, the commonest insect recovered from grain shipments. It is about one-sixth of an inch long. *a*, Beetle; *b*, larva; *c*, pupa; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle, showing antenna; *f*, same of the rust-red flour beetle. (Chittenden)

about 13 years ago from specimens taken in Texas. It is not known to be very widely distributed in the United States, but is likely to be found in mills and granaries in the South.

BROAD-HORNED FLOUR BEETLE

The broad-horned flour beetle, *Gnathocerus cornutus* Fab., owes its name to the peculiar structure of the mandibles or jaws of the male beetle, which are armed with a pair of broad, stout horns as shown in Figure 52. It is a robust, reddish-brown beetle, about one-sixth of an inch long; closely resembling the other flour beetles in appearance, but easily distinguished by the peculiar structure of the jaws. It is cosmopolitan in distribution and occurs frequently in the Southern States. It prefers to feed in flour and meal, but is found in a variety of grains. The adult beetles frequently live for a year or longer, the females laying from 100 to 200 eggs each. The small

[1] A closely related species, *Latheticus prosopsis* Chittn., is shown in Figure 51.

white eggs hatch in from four to five days in warm weather, and development from egg to adult takes place in about eight weeks.

SLENDER-HORNED FLOUR BEETLE

The slender-horned flour beetle, *Gnathocerus maxillosus* Fab., is closely related to the preceding species and is of similar form and

FIGURE 50.—Long-headed flour beetle. Chittenden)

FIGURE 51.—*Latheticus prosopis*. (Chittenden)

FIGURE 52.—The broad-horned flour beetle. (Chittenden)

appearance. It is about one-eighth of an inch in length, and, in addition to its smaller size, it may be distinguished from the broad-horned flour beetle by the shape of the horns with which the mandibles or jaws of the male are armed. In this species (fig. 53) the horns are slender and incurved. Its habits are similar to those of the preceding species.

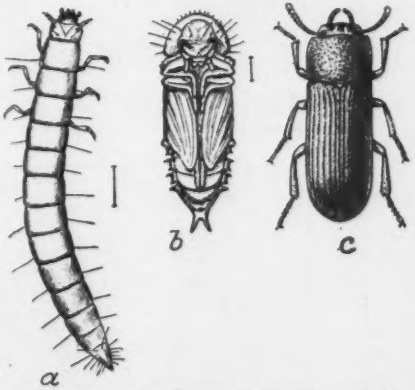

FIGURE 53.—The slender-horned flour beetle; *a*, Larva; *b*, pupa; *c*, beetle. (Chittenden)

SMALL-EYED FLOUR BEETLE

The small-eyed flour beetle, *Palorus ratzeburgi* Wissm. (fig. 54), is the smallest of the so-called flour beetles that infest grain and grain products in this country. It is a tiny, flattened, shiny, reddish-brown beetle, somewhat oblong in form and measuring about one-twelfth of an inch in length. It occurs throughout the world and is widely distributed in this country. It prefers ground products in which to breed, but is not infrequently found in stored grains.

A closely related species (*P. depressus* Fab.) more common in Europe but occasionally found in this country is very similar in appearance and habits to the small-eyed flour beetle.

TOBACCO BEETLE

The tobacco beetle, *Lasioderma serricorne* Fab., is a small, robust, oval, reddish-yellow or brownish-red beetle, with head bent down nearly at right angles to the body, giving the beetle a humped appearance when viewed from the side as shown in Figure 55. It varies in size, but is usually about one-tenth of an inch long. It is found in all temperate, subtropical, and tropical regions and infests tobacco and many other stored products. It breeds in a variety of seeds and may occasionally be found attacking grains left long in storage in original sacks.

FIGURE 54.—The small-eyed flour beetle. (Chittenden)

DRUG-STORE BEETLE

The drug-store beetle, *Sitodrepa panicea* L., is very similar in appearance to the tobacco beetle, to which it is closely allied, but differs from it by being more elongate in proportion and in having the wing covers distinctly striated. It is about one-tenth of an inch long. It is cylindrical and uniform light brown; its body is covered with a fine silky pubescence. (Fig. 56.) The larva or grub is very

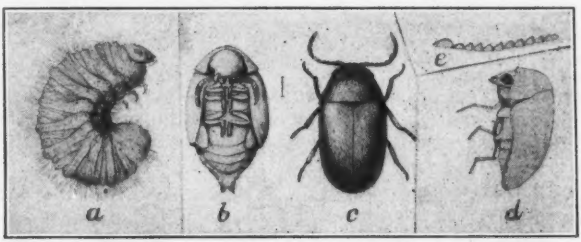

FIGURE 55.—The tobacco beetle never attacks grain unless it has been stored for long periods. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden)

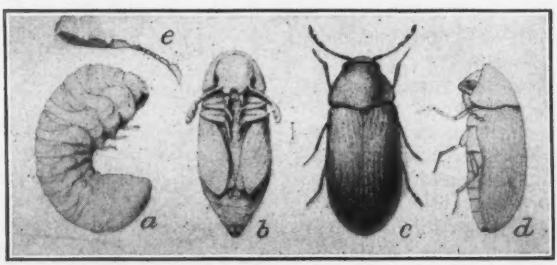

FIGURE 56.—The drug-store beetle never attacks grain unless it is stored for long periods unmolested. *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. (Chittenden)

much less hairy than that of the cigarette or tobacco beetle, as a comparison of Figures 57 and 58 will show. It is known as the drug-store beetle from its habits of feeding on almost all drugs found

in pharmacies. It is a very general feeder, attacking a great variety of stored foods, seeds, and other materials, and has been said to "eat anything except cast iron." It is frequently found in storehouses and granaries in all parts of the world.

FIGURE 57.—The tobacco beetle: Head and leg of larva. (Chittenden)

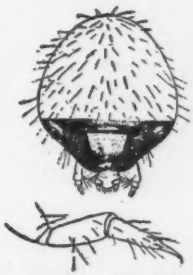

FIGURE 58.—The drug-store beetle: Head and leg of larva. (Chittenden)

The eggs of this beetle are laid in almost any dry organic substance. The small white grubs emerging from the eggs tunnel through these substances and when full grown pupate in small cocoons. The entire life cycle may be passed in less than two months.

FIGURE 59.—The white-marked spider beetle, adult female. (The male is elongate-oval in shape and is not so conspicuously marked as the female)

WHITE-MARKED SPIDER BEETLE

The white-marked spider beetle, *Ptinus fur* L. (fig. 59), is occasionally found infesting stored grain and seeds of various kinds, but rarely causes serious damage. It is an omnivorous feeder, attack-

ing flour, meal, roots, seed, and miscellaneous stored foods. It is about an eighth of an inch in length, reddish brown with four white marks on the wing covers, and, owing to the length of its legs and antennæ, has a somewhat spidery appearance. The larva is white and closely resembles those of the tobacco beetle and the drug-store beetle. It has the habit of forming globular cases of the material in which it is feeding.

BROWN SPIDER BEETLE

The brown spider beetle, *Ptinus brunneus* Dufts., closely resembles the preceding species in size, color, general appearance, and habits. It may be distinguished from the white-marked spider beetle by the fact that the white markings of the wing covers are lacking.

CATORAMA BEETLE

Another beetle closely related to the drug-store beetle and the tobacco beetle and which has similar habits is the catorama beetle, *Catorama* sp., which is shown in Figure 60. It is shiny black and is about one-eighth of an inch long. It is only an occasional pest of stored grain and does not cause serious damage.

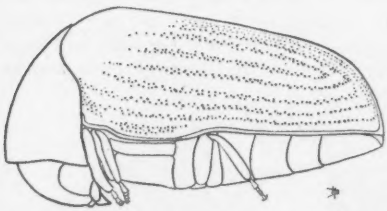

FIGURE 60.—The catorama beetle. This beetle is shiny black

BLACK CARPET BEETLE

The black carpet beetle, *Attagenus piceus* Oliv., is a small oval beetle between two-sixteenths and three-sixteenths of an inch long. The head and thorax are black, but the wing covers may be either black or dark reddish brown, and clothed with short hairs. Its legs and antennæ are dark yellowish in color. The larva is very characteristic and can be readily recognized. It is reddish or golden brown, clothed with short scalelike appressed hairs and provided with a tuft of long hairs at the end of the body, as shown in Figure 61.

As the name indicates, this insect injures carpets, but in addition it is known to breed in grains and cereals, both whole and ground. The larval stages develop very slowly, and there is but one generation each year. The adults appear in greatest numbers during the spring and early summer. It occurs in Europe and Asia and has been reported from all parts of this country. It is of very common occurrence in houses.

LARGER CABINET BEETLE

The larger cabinet beetle, *Trogoderma tarsale* Melsh., is a small, oval beetle about one-eighth of an inch long, its ground color black mottled with reddish brown, covered with gray and light-brown scalelike hairs forming a distinct pattern on the wing covers. The larva somewhat resembles that of the black carpet beetle in appearance. It is about one-eighth of an inch long, reddish brown above and whitish beneath, with body covered with short yellowish-brown

hairs and with a tuft of short hairs at the tail end. (Fig. 62.) It is well known for its habit of breeding in dead insects and animal substances and is not infrequently found living in grain, flaxseed,

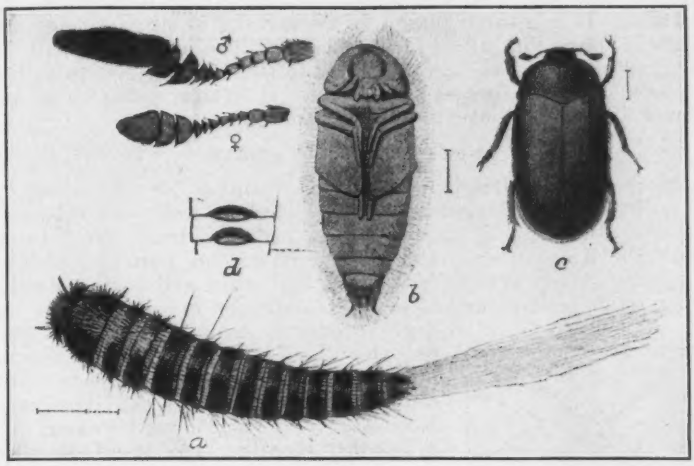

FIGURE 61.—The black carpet beetle is chiefly a pest of sample grains, or found in grain dust about elevators or storage bins. *a*, Larva; *b*, pupa; *c*, beetle; *d*, dorsal abdominal segments of pupa; ♂, antenna of male beetle; ♀, antenna of female beetle. (Howard)

castor beans, pumpkin seed, etc. It often becomes a nuisance in laboratories by attacking sample lots of corn, wheat, etc.

SMALL CABINET BEETLE

The small cabinet beetle, *Anthrenus verbasci* L., is somewhat similar in appearance to the larger cabinet beetle but smaller and of different color. It varies in length from one-sixteenth to two-sixteenths of an inch, and is black with yellowish-white scales that form a broad band across the back and give the body a mottled appearance. The habits of the adult and early stages of this insect are similar to those of the larger cabinet beetle. It is occasionally found in flour mills and granaries, where it infests grain and grain products.

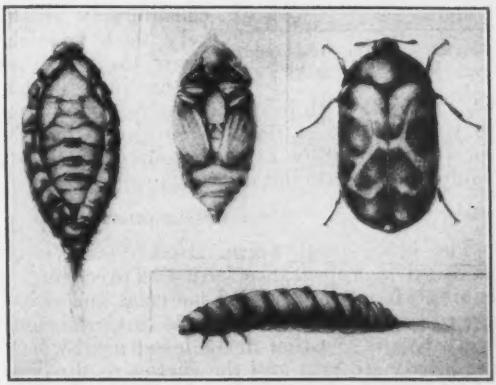

FIGURE 62.—The larger cabinet beetle: At left, pupa within larva skin; in center, pupa; at right, beetle; below, well-grown larva

MUSEUM BEETLE

The museum beetle, *Anthrenus museorum* L., is closely allied to the preceding beetle and resembles it in size and form. Its body is black, covered with yellowish and whitish scales, giving it a spotted appearance. It is a small plump beetle varying in size from one-sixteenth to one-eighth of an inch in length. The larvæ are small, active, hairy grubs with habits similar to those of the two preceding species. They are occasionally found in grains, both whole and ground, but do not cause noticeable damage.

TWO-BANDED FUNGUS BEETLE

The two-banded fungus beetle, *Alphitophagus bifasciatus* Say, is a handsome little elongate-oval beetle slightly less than an eighth of an inch long. It is reddish brown with two broad black bands across the wing covers. Its characteristic color pattern is shown in Figure 63. It is distributed over the world and is in general a feeder on fungi and molds, being a scavenger in refuse grain and grain products, decaying vegetable matter, etc. It is frequently found around mills and storehouses where waste material is allowed to accumulate. The larvæ have been bred from moist cornmeal and in spoiled cereals. The insect is often found in the holds of grain ships in wet or damaged grain.

FIGURE 63.—The two-banded fungus beetle. Adult

BLACK FUNGUS BEETLE

The black fungus beetle, *Alphitobius piceus* Oliv. (fig. 64), resembles the mealworm beetles in form and color but is considerably smaller. It is black or a very dark reddish brown and measures from three-sixteenths to four-sixteenths of an inch in length. The larva (fig. 64, *a*) is yellowish brown and is very similar in form and appearance to young larvæ of the meal worms. This beetle is often found in the same situations as the two-banded fungus beetle. It breeds in damp moldy grain but causes no injury to grain that is sound and dry.

LESSER MEAL WORM

The lesser meal worm, *Alphitobius diaperinus* Panz., is almost identical in appearance with the preceding species and has similar habits. It prefers spoiled material and does not cause serious damage to sound grain. It may be distinguished from the black fungus beetle by the fact that in the lesser meal worm the sides of the thorax are nearly straight and the surface is finely and sparsely punctured, whereas in the black fungus beetle the sides of the thorax are curved and the surface is coarsely and profusely punctured.

CORN SAP BEETLE

The corn sap beetle, *Carpophilus dimidiatus* Fab., may be readily recognized by its peculiar wing covers, which are short and truncate, leaving the tip of the abdomen exposed as shown in Figure 65. It is a

small, dark-brown beetle with lighter colored wing covers, oblong-ovoid in shape, and varying in length from one-tenth to one-eighth of an inch. It normally feeds in rotting and decaying fruit and vegetation and in the sap exuding from injured plants. It is quite numerous in

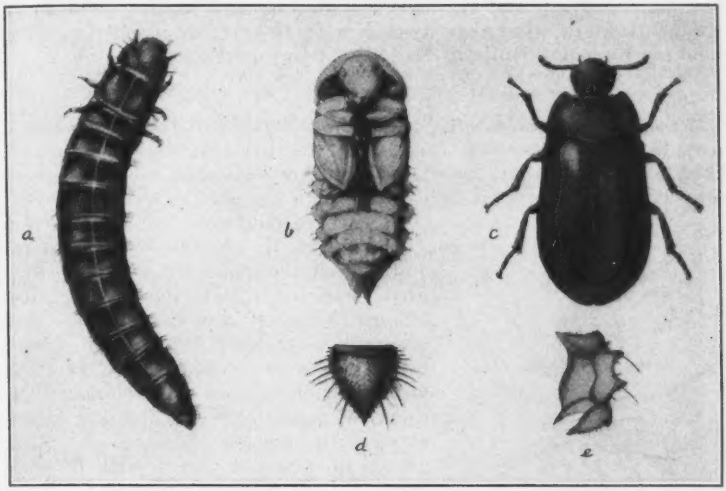

FIGURE 64.—The black fungus beetle: *a*, Larva; *b*, pupa; *c*, adult; *d*, caudal segment of larva (Schlödte); *e*, lateral plate of pupa. (Schlödte)

cornfields in the South, swarming over the damaged ears and feeding and breeding in the decaying kernels. It is attracted to damp and decaying grain but is seldom found in grain that is clean and dry.[2]

FIGURE 65.—The corn sap-beetle. Adult

A closely related beetle (*Carpophilus humeralis* Murray) that has been introduced from abroad and is becoming more and more abundant is similar in form to the corn sap beetle, but is slightly larger and is uniform, shiny, dark brown all over. Its habits are very similar to those of the preceding species.

BOOK-LICE OR PSOCIDS

Book-lice or psocids, *Troctes divinatoria* Fab. *et al.*, are minute, pale, soft-bodied, louselike insects, about one thirty-second of an inch long, with long, slender antennæ, differing greatly in appearance from other grain-infesting insects. (Fig. 66.) They may be whitish, almost transparent, or quite dark.

[2] *Carpophilus pallipennis* Say, a purely flower-infesting beetle, has been occasionally reported as infesting stored corn. In these cases large specimens of the corn sap beetle which closely resemble this species were probably mistaken for it.

Psocids are of very common occurrence and may be found in nearly any situation. They are almost omnivorous, feeding on any animal or vegetable matter. They are frequently found in grain, but while they have jaws and are capable of feeding upon solid materials, they may be disregarded as pests of grain. They are frequently very abundant in grain and are here recorded because of the curiosity of persons to know what they are. For further information regarding them see Farmers' Bulletin 1104, Book-Lice or Psocids.

MITES

Mites, *Tyroglyphus* spp., are pale-colored, soft-bodied creatures provided with numerous long hairs, as illustrated in Figure 67. They are microscopic in size. As a low estimate the number of mites that may be found on 1 square inch has been placed at 100,000. They are often found in stored grain and occasionally increase with such rapidity that the grain seems to be fairly alive with them. During heavy infestations their cast skins and dead bodies accumulate in fluffy light-brown masses beneath the sacks of grain. If these accumulations are on a warehouse floor, they roll up into piles, which are blown about with each gust of wind. No other group of pests in grain will produce these masses. When present in large numbers they promote sweating, impart a disagreeable odor to the grain, and may cause damage by their feeding. Fortunately the mites that attack grain are themselves preyed upon by predacious mites which usually become abundant enough to kill the grain mites in a comparatively short time. If they do not, the screening and fanning of grain will usually reduce mite infestations to a point where no injury takes place.

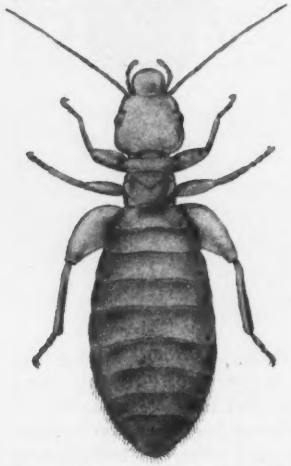

FIGURE 66.—Book-louse or psocid

PARASITES OF GRAIN PESTS

Grain in bulk is often seen swarming with small, black, wasplike insects of a size and appearance shown in Figure 68. These do not cause injury to grain. On the contrary, they are beneficial, as they are attacking and killing the grain weevils and grain moths. While parasites kill a large number of grain insects they unfortunately can not be considered of great importance from the standpoint of grain protection, for by the time the grain insects have been controlled by parasites the grain itself has become very badly damaged. For this reason the appearance of a large number of parasites in grain cars or elevators should be disregarded and the grain treated as though parasites were not present.

Grain dealers frequently find a small threadlike white worm, *Scenopinus fenestralis* L. (fig. 69), about three-quarters of an inch long in grain dust beneath sacks or in the bottoms of bins. This

is the larva of a small black fly to be found crawling upon windows of granaries and flour mills. Because of this habit it is called the window-pane fly. Its threadlike larva does no harm to grain but is predacious upon the larvæ of grain pests and clothes moths. It is not abundant enough to be of value in protecting grain.

HOW GRAIN BECOMES INFESTED

Grain may become infested in a number of ways. It is never possible to settle satisfactorily litigation over responsibility for insect damage to grain without a thorough knowledge of the history of the particular grain shipment involved.

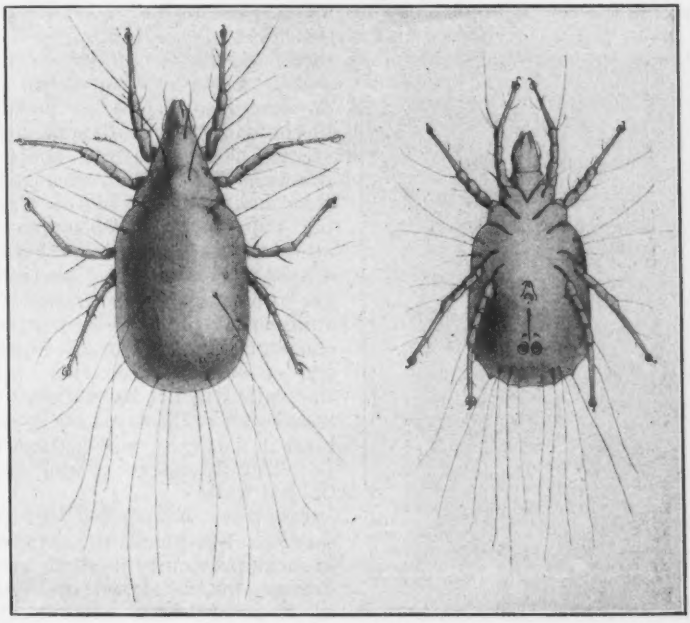

FIGURE 67.—Grain mites. (Howard)

Several of the worst insect pests of grain, notably the Angoumois grain moth and the rice or black weevil, fly to the grainfields from near-by cribs and begin their attack upon the maturing grain. In the case of wheat and similar small grains, the eggs of the insect are laid directly upon the heads of grain. In the case of corn the insects can infest only those kernels that are exposed because of poorly developed or damaged shuck covering. In cornfields, especially in the South, where insect infestation occurring in the field is most severe, there are a sufficiently large number of exposed kernels to bring about slight, though widespread, infestation.

It is probably true that in well-grown crops of corn the percentage of kernels infested before the crop is ready for harvest is very small, and throughout the Middle and Northern States is a negligible factor. In the Gulf Coast States, especially in upland fields, the infes-

tation often is very severe. In the case of wheat, grown particularly along the Ohio River, in southern New Jersey, in Pennsylvania, Maryland, Delaware, Virginia, and southward, the field infestation may be much more general than is now believed. Newly threshed wheat from Maryland arriving in September on the Baltimore market showed infestation ranging up to 6 per cent. While these infestations occurring in the grain before it is harvested are usually unavoidable, they are of great importance as "leaven" which in storage may result in a general infestation of an entire crop, in heating, and in much damage.

After grain has been harvested it is often stored in bins, storehouses, or barns that have held, or still hold, infested grain and which have not been thoroughly cleaned. Wooden bins and wooden partitions in grain storehouses and in the holds of grain-carrying ships become the nesting places for an incredibly large number of grain pests. Certain of these can and do bore into the softer portions of the partitions and timbers that are used over and over again as dunnage, and the excavations they make serve as hiding places, not only for themselves but all other species associated with them. Unless such bins and partitions are thoroughly disinfected by fumigants, these hidden insects can not be killed. The mere spraying of contact insecticides upon the walls will not reach them. If uninfested grain is placed in such bins, it naturally will become infested by the insects coming from the bin walls.

FIGURE 68.—Hymenopterous parasite of grain pests. Adult parasite resting upon a kernel of wheat. These tiny gnatlike insects are beneficial but their help usually comes too late to prevent damage to the crop in which they are most abundant

Likewise, uninfested grain should not be placed for shipment in sacks previously used for grain storage, for, as shown in Figure 32, these old sacks often harbor insects unless they have been treated by heat or fumigation. Certain extensive and costly infestations have been traced directly to the use of secondhand untreated grain sacks.

Grain stored in the open or in poorly constructed cribs or bins may become infested by insects flying in from outside sources.

HOW TO PREVENT PRIMARY INFESTATION

Infestation of grain in the field can not be entirely prevented, but by proper precautions it can be reduced to a minimum. The first generation of insects in the maturing grain is usually small, and if the grain is cut as soon as ripe, threshed as soon as dry, and then placed in storage in clean, deep bins the damage from this source will be very slight. It is when the grain is left in the field long after it is ripe that serious infestation results, for the insects increase in one or two generations to enormous numbers. In the case of corn

in the field, only those ears that are damaged or through poor shuck development have kernels exposed are subject to the attack of grain insects. Farmers should therefore grow a variety of corn that develops a long tight shuck.

Newly harvested small grains should not be stored unthreshed for any length of time, as in this condition they are very susceptible to infestation. If promptly threshed and stored in deep bins, only a thin layer on top of the bin is likely to become infested. Corn may be stored in the shuck if the husk is long and tight and fully covers the tip, but all ears with loose, broken, short, or damaged husks should be shucked and stored separately.

Clean grain should never be stored in old bins, granaries, or storehouses until they have been thoroughly cleaned and freed from the accumulations of waste grain and other materials harboring grain insects. Timbers in bins, granaries, or holds of ships that have become infested with grain insects should be destroyed or treated before being used again. Steel or concrete bins are highly desirable owing to the ease with which they are cleaned.

FIGURE 69.—Larva of a kind of fly that preys upon grain beetles and mites. This white threadlike worm is sometimes found in grain dust and attains a length of about three-fourths of an inch; while interesting, it is of no practical value

Bags of all kinds that have previously held grain should not be allowed in granaries or warehouses or be refilled until they have been sterilized by heat or otherwise freed from insects. The use of tight cribs will keep the grain free from infestation by insects that might fly in from the outside.

THE TREATMENT OF INFESTED GRAINS

Insects infesting stored grain can be destroyed by the use of heat, or by fumigation with poisonous gases. These remedial measures are mentioned only briefly in this bulletin.

HEAT

A temperature of 120° to 130° F., maintained for a short time, will kill all stages of grain-infesting insects, without injuring the germinating quality of the grain. Owing to the difficulty of subjecting the grain to such a temperature this method of control is used chiefly by millers and large grain dealers who are equipped with commercial driers suitable for the purpose.

FUMIGATION

Carbon disulphide, carbon tetrachloride, and hydracyanic-acid gas are the fumigants in most common use to-day for treating infested grain. All things considered, carbon disulphide is the most effective fumigant for treating grain in bulk. It is a colorless liquid

which evaporates on exposure to air, forming a vapor that is heavier than air. If applied at the top of a gas-tight bin of grain, the gas will penetrate down through the grain, killing the insects without injury to sound grain.

Carbon disulphide has the great disadvantage that its vapor is highly inflammable and when mixed with certain proportions of air will explode if ignited. Notwithstanding this fire hazard, which must always be taken into consideration, carbon disulphide is in general use on farms for the protection of grain in cribs. For further information on fumigation with carbon disulphide see Farmers' Bulletins 799, 1029, and 1483, published by the United States Department of Agriculture.

Carbon tetrachloride is not very effective as a grain fumigant when used alone, but owing to its noninflammability it is used extensively in the manufacture of grain fumigants containing small quantities of more powerful but inflammable compounds. Several such mixtures containing carbon tetrachloride, sulphur dioxide, and a small quantity of carbon disulphide are in common use. They are less effective than carbon disulphide alone, but considerably more effective than carbon tetrachloride and, while not entirely free from fire hazard, they are much safer than carbon disulphide.

Hydrocyanic-acid gas generated from calcium cyanide has been used to some extent during the last few years to fumigate grain in large elevator bins. The calcium cyanide, in a finely divided state, is incorporated into the flow of wheat as it enters the bin. Hydrocyanic-acid gas generated from calcium cyanide so distributed through the mass of wheat in the proportion of 25 pounds of the chemical to 1,000 bushes of wheat will, according to the experiments of some, kill all the weevils and does not injure the grain for milling purposes. Grain so treated, however, may temporarily carry an odor, and while this odor ordinarily seems to be of no consequence from the milling and making standpoint, the grain will be sample graded by Federal inspectors should the odor be considered permanent. This type of fumigation is a highly specialized one, calling for the use of patented equipment.

Chloropicrin is a noninflammable tear gas, highly toxic as a fumigant for grain insects. The development of better methods of application may greatly increase its use for fumigating grain.

Ethylene oxide is a valuable fumigant for stored grain. Used in the proportion of 2 or 3 pounds per 1,000 bushels of wheat, it is effective against grain insects when used in combination with carbon dioxide. The mixture is best suited for use in grain elevators where equipment is available for mixing the material with the grain as the bins are being filled. The ethylene-oxide mixed with carbon dioxide, when used as recommended, is noninflammable and nonexplosive.

Further information regarding the control of grain pests will be found in Farmers' Bulletin 1483, Control of Insect Pests in Stored Grain.

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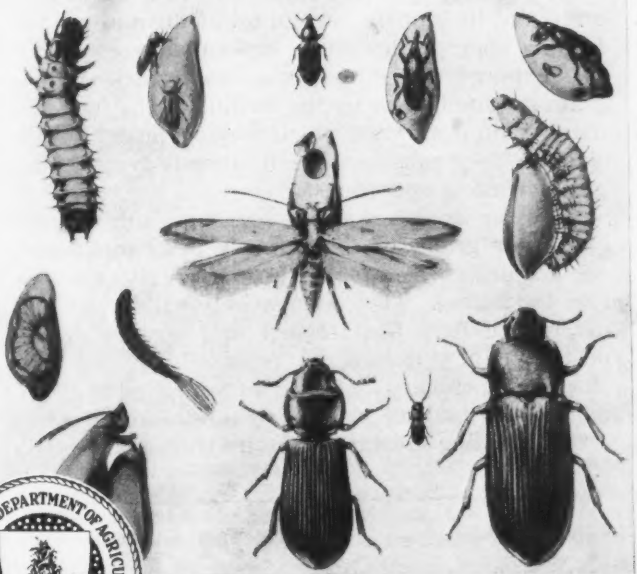
STORED-GRAIN PESTS



UNITED STATES DEPARTMENT OF AGRICULTURE

MOST of the damage done by insects to grain in storage and shipments is brought about by four species. These are the granary weevil, the rice or black weevil, the lesser grain borer or Australian wheat weevil, and the Angoumois grain moth. Other species or groups of species described in this bulletin can cause great damage to grain if storage conditions are unusually favorable for their increase. Yet if grain in the unbroken kernel remains unaffected by the four insects mentioned, it is not likely, in commercial storage or shipments, to be sufficiently affected by other insects to cause appreciable loss.

The secondary pests discussed herein are for the most part surface feeders in both adult and larval stages. Some may eat their way into kernels of grain and lie hidden there; most of them are found feeding upon grain dust or broken surfaces of kernels exposed either by mechanical injuries to the grain in handling or by the feeding of the four primary grain pests with which they are usually associated. They can therefore be largely removed by grain-cleaning operations.

With the exception of the lesser grain borer, the larvae, or grubs, of the primary pests mentioned are not ordinarily capable of a free existence outside the kernel. They live entirely within the kernel, where they feed unseen and usually unsuspected. They cannot be removed by ordinary cleaning machinery and must be controlled by other means. Methods of preventing infestation of grain and of treating infested grain are discussed briefly.

Washington, D. C. Issued April 1922; revised December 1938

STORED-GRAIN PESTS

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POPULAR CLASSIFICATION OF GRAIN PESTS

SINCE THE ESTABLISHMENT of the Federal standards for grain under the provisions of the Grain Standards Act, Federal grain supervisors and federally licensed grain inspectors have been required to identify the various species of "live weevils and other insects injurious to stored grain" which may be present in the grain. Uniform names for grain insects should be used. Such uniform terminology will indicate definitely to all interested persons, including shipper, purchaser, and elevator operator, the exact nature of the insect found. Of the four major pests, the granary weevil, the rice or black weevil, and the lesser grain borer may well be called grain weevils. The fourth of the major pests, the Angoumois grain moth, so destructive to wheat and corn, may be called grain moth. Other insects likely to be found in any lot of grain may be called simply beetles, moths, and mealworms, for their presence

usually does not indicate a condition likely to affect the trade, provided that after the grain has reached the elevator it is screened and fanned to remove these insects.

In this bulletin are discussed grain weevils, grain borers, grain moths, flour moths, grain and flour beetles, mealworms, dermestid beetles, spider beetles, miscellaneous beetles, booklice, or psocids, silver-fish, cockroaches, flour or grain mites, and parasites of grain pests.

GRAIN WEEVILS

Of the four true weevils that attack grain in the United States, only two are of primary importance—the granary weevil and the rice or black weevil. The broad-nosed grain weevil and the coffee-bean weevil are of minor importance, except locally. These four weevils have elongated beaks or snouts, as the illustrations show, though the beak of the coffee-bean weevil is greatly reduced.

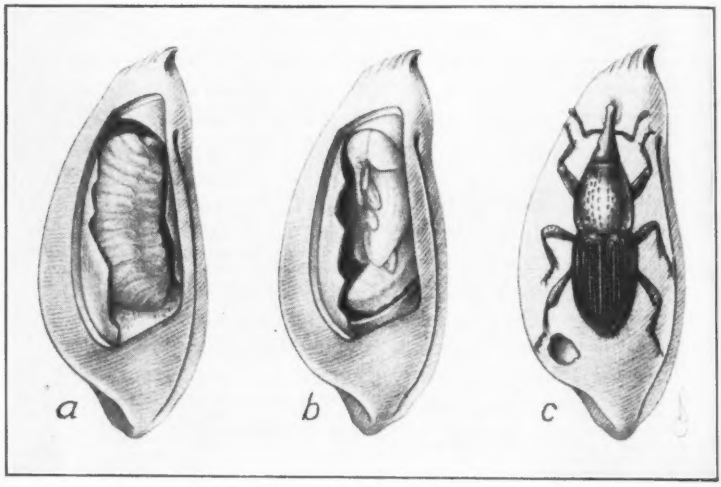

FIGURE 1.—Life stages of the granary weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult. Note hole in kernel made by the adult in order to leave the seed and hole that it is eating into the kernel for the purpose of laying eggs. The adult is never more than three-sixteenths of an inch long.

GRANARY WEEVIL

The granary weevil (*Sitophilus granarius* (L.)) (fig. 1) is a small, moderately polished, chestnut-brown or blackish beetle with head prolonged into a long slender snout, at the end of which are a pair of stout mandibles or jaws. It is not more than three-sixteenths of an inch long and often is smaller. It has no wings under its wing covers, and the thorax is well marked with longitudinal punctures, two characteristics that distinguish it from the closely related rice weevil, with which it is often found associated. The well-grown footless, whitish grub or larva and the pupa are shown in figure 1, *a* and *b*. The granary weevil is one of the oldest known insect pests,

is a universal feeder upon grains, and is cosmopolitan, having been carried by commerce to all parts of the world. It prefers a temperate climate and is more frequently found in the Northern States than in the South.

Both adults and larvae feed voraciously on a great variety of grains. The adult weevils live, on an average, from 7 to 8 months, the females laying from 50 to 250 eggs each during this period. Before laying her eggs the female bores a small hole in the grain berry with her mandibles. When this has been made she turns about and lays in it an egg, which she then covers with a gelatinous fluid that seals the hole. The small, white, fleshy, and legless grubs that hatch from the eggs burrow about inside the kernels. When fully grown, these transform to the pupal stage and then into the adult-weevil form.

In warm weather the granary weevil requires about 4 weeks to complete its development from the egg to the adult weevil. The developmental period is greatly prolonged by cold weather.

RICE OR BLACK WEEVIL

The rice or black weevil (*Sitophilus oryzae* (L.)) is a small snout-beetle which varies considerably in size but rarely measures more than one-eighth of an inch in length (fig. 2). It varies in color from reddish brown to nearly black and is usually marked on the back with four light reddish or yellowish spots. It closely resembles the granary weevil in form, but it has well-developed wings beneath its wing covers, differs in color and markings, and has the thorax densely pitted with round, instead of longitudinal punctures. Figure 2 gives a good impression of the appearance of the rice weevil and its earlier stages.

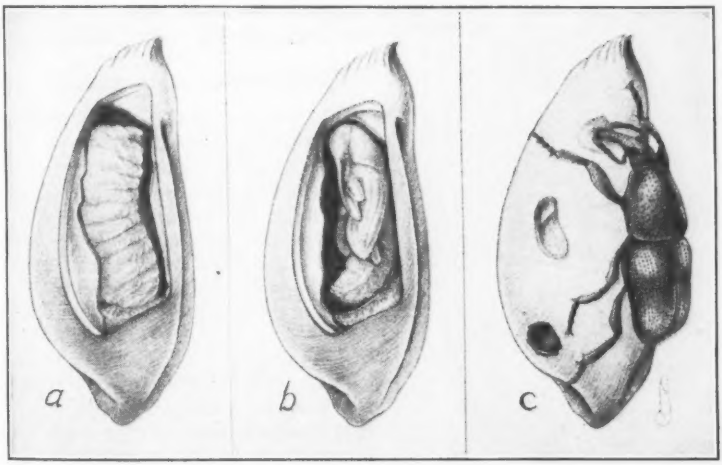

FIGURE 2.—Life stages of the rice or black weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult feeding upon kernel. Note in *c* the hole in lower portion of kernel made by the adult on leaving the seed and at two points higher up shallow holes made by the adult in feeding upon the seed after emergence. The adult rarely measures more than one-eighth of an inch in length.

This weevil has been known from early times. It is found in all parts of the world where grain is used and is one of the very worst pests in stored grain. It is particularly abundant in warm countries, where it breeds continuously and rapidly destroys all unprotected grain. Throughout the South it causes tremendous losses to corn (fig. 3), reducing the kernels to dry powder and hulls, and is the commonest of the serious pests of commercial grain shipments.

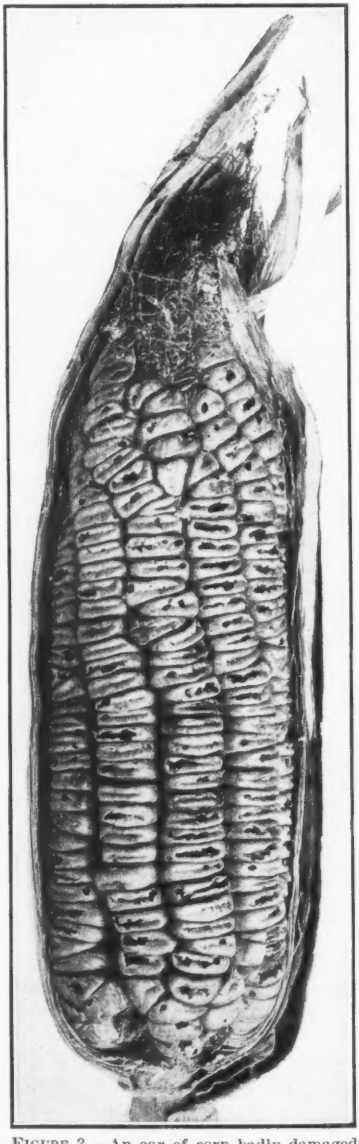

FIGURE 3.—An ear of corn badly damaged by rice or black weevils. This ear has been hit against a table to jar loose the powdery substance, sometimes called the farinaceous material, and so reveals the great damage done by the weevils.

The adult weevil lives, on an average, 4 or 5 months, each female laying between 300 and 400 eggs during this period. The early stages are almost identical in habit and appearance with those of the granary weevil and need not be further described. The rice weevil is a strong flier. The adults fly from granaries to the fields of grain and there start the infestation that often proves so disastrous after the grain has been harvested. During summer weather the egg, larval, and pupal stages may be passed in as few as 26 days. This period, of course, is greatly prolonged during cool or cold weather. For a further discussion of this pest see Farmers' Bulletin 1811, Control of Insects Attacking Grain in Farm Storage.

BROAD-NOSED GRAIN WEEVIL

The broad-nosed grain weevil (*Caulophilus latinasus* (Say)) is a small dark-brown snout beetle slightly less than one-eighth of an inch long. In form and color it resembles the granary weevil somewhat but differs from it and from other grain-infesting weevils by having a short, broad snout (fig. 4).

This weevil is occasionally found in Georgia and South Carolina and is widespread in Florida, where it is a serious pest of stored grains, but it is not found in grains grown in the North. It is unable to breed in dry, hard, uninjured grain, but attacks soft or damaged grain, or grain that has been attacked by other grain insects. It is

a strong flier, and, like the rice weevil, flies to the cornfields and infests the grain before it becomes fully hardened.

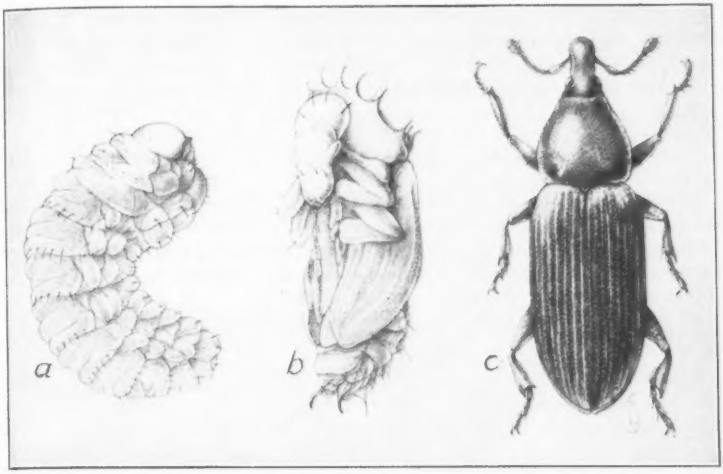

FIGURE 4.—The broad-nosed grain weevil: *a*, Full-grown larva; *b*, pupa; *c*, adult weevil. The adult weevil is slightly less than one-eighth of an inch long.

The adult weevils normally live for about 5 months, and during this time the females lay between 200 and 300 small white eggs, usually in broken portions of the grain. The eggs hatch in a few days, and the small, white, legless grubs feed on the softer portions of the grain until fully grown. They then change to a white pupal form, which in a few days transforms to the adult beetle and cuts its way out of the grain. In summer the period from egg to adult is about 1 month.

COFFEE-BEAN WEEVIL

The coffee-bean weevil (*Araecerus fasciculatus* (Deg.)) is a very active, robust dark-brown beetle from two-sixteenths to three-sixteenths of an inch long, clothed with a mottled light- and dark-brown pubescence. It may be easily recognized from figure 5.

This weevil is found in many countries and is extremely abundant in the Southern States, where it breeds in dried fruit, coffee berries, cornstalks, corn, and the seed and seed pods of an almost endless variety of plants. It is a strong flier and is frequently to be seen in the cornfields of

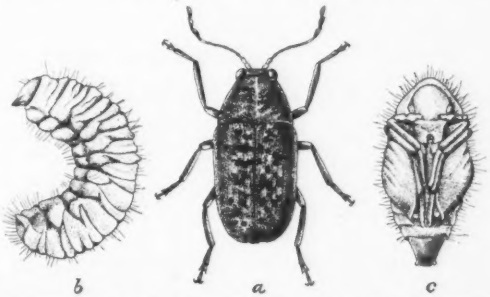

FIGURE 5.—The coffee-bean weevil: *a*, Adult; *b*, well-grown larva; *c*, pupa. The adult is about three-sixteenths of an inch long.

the South on the exposed and damaged ears. It lays its eggs in the soft kernels of corn, and breeding continues after the corn has been harvested and placed in storage. It does not cause much damage to corn in storage, as the corn becomes too hard to be attractive. It may, however, be very abundant locally in corn in Florida during the first 3 months of storage and has been reported as completely destroying a sack of kafir seeds in Honolulu. Taking the country at large, the coffee-bean weevil is a very minor grain pest.

GRAIN BORERS

Three species of grain borers are now established in the United States. The lesser grain borer is now widespread in the grain centers of this country and is a serious pest of stored grain. The larger grain borer and the bamboo borer are confined to the Southern States and are not of commercial importance.

LESSER GRAIN BORER

The lesser grain borer (*Rhizopertha dominica* (F.)) is one of the smallest beetles injurious to grain in this country. It is known to many grain dealers more popularly as the Australian wheat weevil

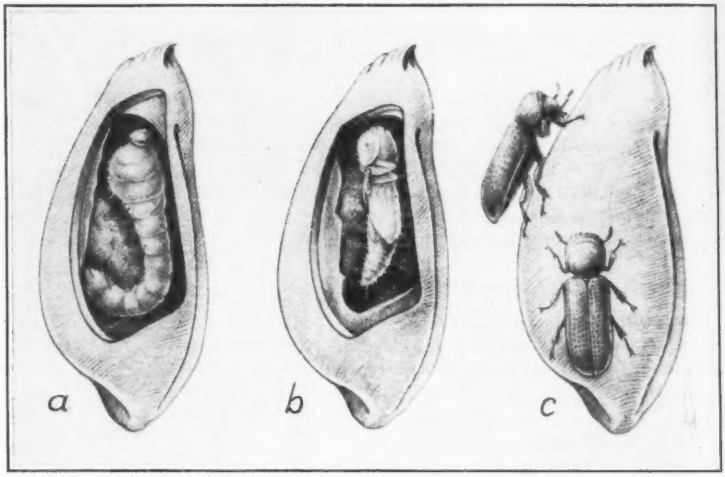

FIGURE 6.—The lesser grain borer in and on wheat kernels: *a*, The well-grown larva; *b*, the pupa; *c*, two adult weevils. Adult borer is about one-eighth of an inch long.

because of the large supplies of wheat infested by it that reached this country from Australia during the World War. It is widespread in the Gulf States, and grain samples infested with this beetle are to be found in all large grain centers. It is readily distinguished from other grain pests by its slender cylindrical form and small size. It is polished dark brown or black, with a somewhat roughened

surface, about one-eighth of an inch long and one thirty-second of an inch wide. The larval, pupal, and adult stages are illustrated in figure 6. It belongs to a family (Bostrichidae) of beetles that have the head turned down under the thorax and are armed with powerful jaws with which they can cut directly into wood. Originally native to the Tropics, the lesser grain borer has spread through commerce to all parts of the world.

Both beetles and larvae cause serious damage in warm climates, attacking a great variety of grains. The destruction of which they are capable is shown by the wheat kernels of figure 7, which are literally riddled by the boring adults and their young. The damaged kernels are always surrounded by powder from the chewed-up grain. The females lay from 300 to 500 eggs each, dropping them singly or in clusters in the loose grain. The eggs hatch in a few

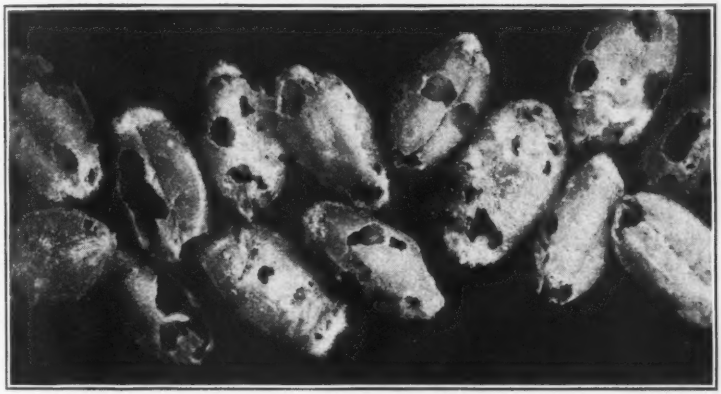

FIGURE 7.—Kernels of wheat thoroughly riddled and devoured by the boring and feeding of the lesser grain borer and its larva.

days, and the small whitish grubs crawl actively about the grain, feeding on the flour produced by the boring of the beetles, or boring directly into grains that have been slightly damaged. They complete their growth within the grain, transform to white pupae, and in time change to adult beetles which cut their way out of the grain. The period from egg to adult in summer is said to be about a month.

LARGER GRAIN BORER

The larger grain borer (*Stephanopachys truncatus* (Horn)), is a small, dark-brown, elongate-cylindrical beetle about one-sixth of an inch long. As may be seen in Figure 8, it is very similar in appearance to the lesser grain borer, but it may be distinguished by its larger size and comparatively smooth, polished surface.

This beetle is a tropical insect not as yet widely distributed in this country. It is occasionally found infesting corn (fig. 9) in the South. It has been reported from Texas, California, and the Dis-

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trict of Columbia. Like the lesser grain borer, it belongs to a family of beetles (Bostrichidae) that are mainly destructive to timber

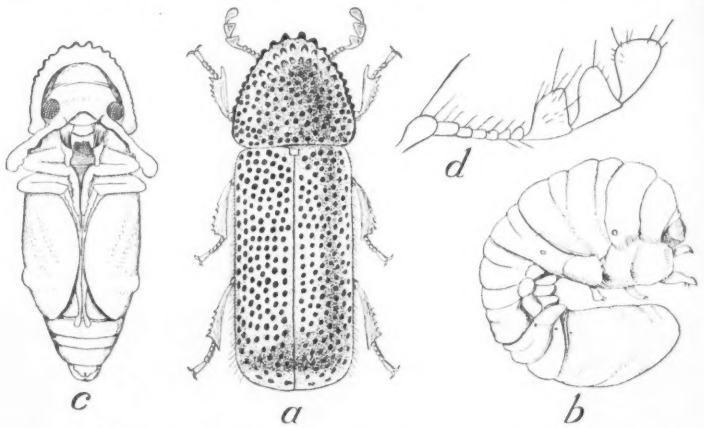

FIGURE 8.—Adult and immature stages of the larger grain borer: *a*, Adult insect; *b*, larva; *c*, pupa; *d*, antenna of adult. The adult beetle is about one-sixth of an inch long; the antenna in *d* is highly magnified.

and has habits similar to those of that beetle. It also has probably acquired its grain-feeding habits rather recently.

FIGURE 9.—Kernel of corn showing the work of the adult of the larger grain borer.

One other member of the family Bostrichidae, *Dinoderus minutus* (F.), the bamboo borer, occasionally infests stored grain in the United States. It has been recorded from Louisiana and Florida. In general appearance it resembles the larger grain borer.

GRAIN MOTHS

The term "grain moth" includes only those moths capable of destroying sound, unbroken grain kernels. They are not so abundant as the flour moths, which are principally pests in broken, damaged kernels or milled products.

ANGOUMOIS GRAIN MOTH

The Angoumois grain moth (*Sitotroga cerealella* (Oliv.)) is a small bluff or yellowish-brown moth with a wing expanse of about one-half inch. This is the moth most commonly found in infested grain in this country and is not likely to be confused with any other. It attacks all cereal grains, is found in all parts of the world, and is particularly injurious in the South, where it attacks grain both in the field and in storage. In the North it survives the winter, for the most part as larvae in kernels of grain in storage and in scattered wheat in litter, straw piles, and baled straw. The emerging moths fly to the wheatfields in May and deposit eggs upon the developing grain.

Under normal conditions each female lays an average of about 40 eggs, although under favorable conditions individual moths have been known to lay as many of 389 eggs. The eggs, which are white

when first laid, soon change to a reddish color. They are laid on wheat heads, on the exposed tips of ears of corn in the field, or on grain in storage. Upon hatching, the young larva crawls to a kernel of grain and often spins a small entrance cocoon to assist it in boring into the hard kernel. After entering the grain, it feeds on either the endosperm or the germ until fully grown, when it eats out a channel to the outside of the seed and prepares an exit hole through the seed coat by cutting the shell for one-half or three-fourths of the circumference of a circle, making a weakly fastened flap. A silken cocoon is spun, and the larva changes to a reddish-brown pupa. Later a moth pushes its way through the partly cut flap.

The period from egg to adult may be completed in 5 weeks, although development is usually slower than this. In years favorable to this insect great damage is caused to harvested wheat unless it is promptly threshed. As the delicate moths are unable to penetrate beneath the surface of stored grain, infestation is restricted to the surface kernels. Figure 10 shows an ear of corn with the external evidence of a heavy attack by the Angoumois grain moth. Figure 11 shows the successive stages in the development of this insect in a kernel of wheat from the time the egg is laid until the adult appears.

For a further discussion of this insect, see Technical Bulletin 351, Life History of the Angoumois Grain Moth

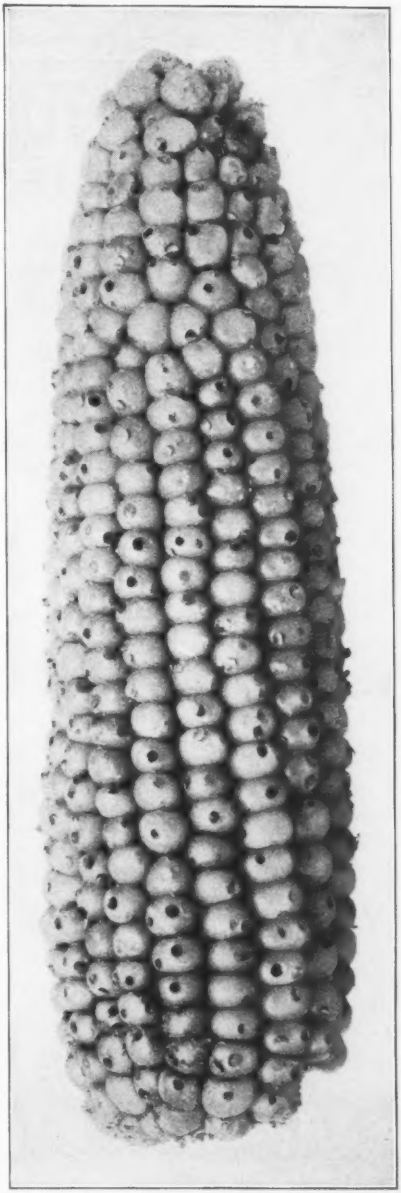

FIGURE 10.—Ear of popcorn showing heavy infestation by the Angoumois grain moth. Note that certain of the kernels have three emergence holes, and that many have served as food for two larvae.

in Maryland, and Farmers' Bulletin 1156, The Angoumois Grain Moth.

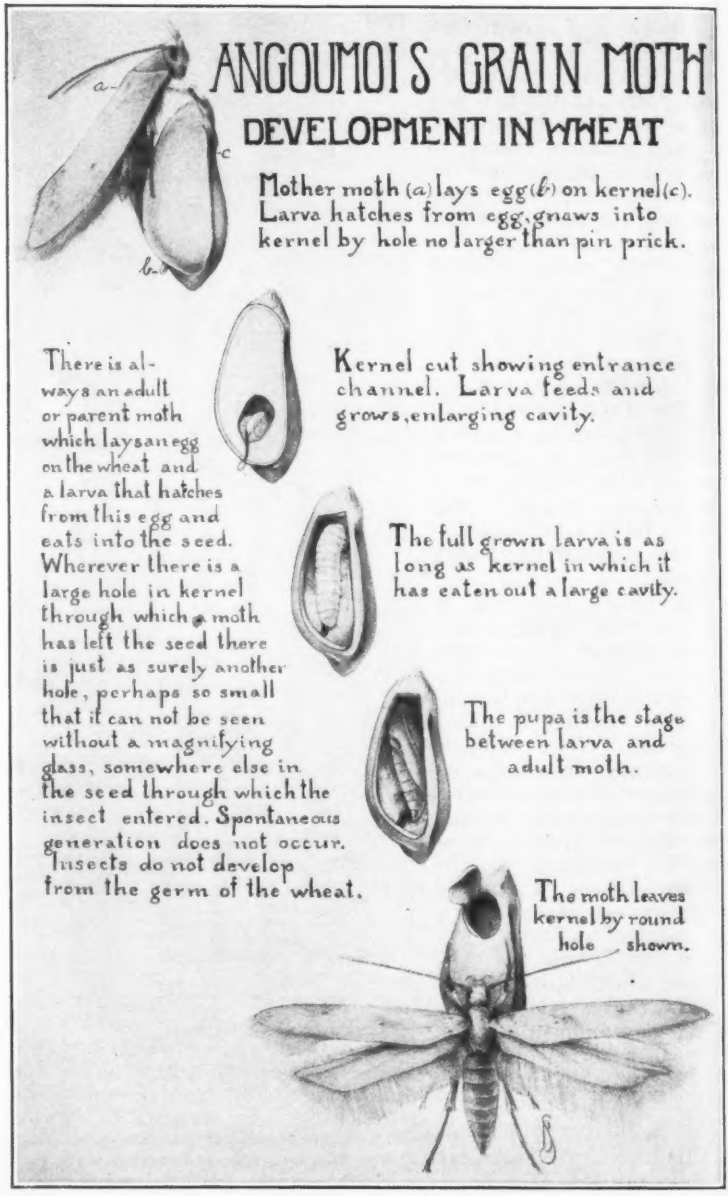
ANGOUMOIS GRAIN MOTH
DEVELOPMENT IN WHEAT
Mother moth (a) lays egg (b) on kernel (c). Larva hatches from egg, gnaws into kernel by hole no larger than pin prick.
Kernel cut showing entrance channel. Larva feeds and grows, enlarging cavity.
There is always an adult or parent moth which lays an egg on the wheat and a larva that hatches from this egg and eats into the seed. Wherever there is a large hole in kernel through which a moth has left the seed there is just as surely another hole, perhaps so small that it can not be seen without a magnifying glass, somewhere else in the seed through which the insect entered. Spontaneous generation does not occur. Insects do not develop from the germ of the wheat.
The full grown larva is as long as kernel in which it has eaten out a large cavity.
The pupa is the stage between larva and adult moth.
The moth leaves kernel by round hole shown.

FIGURE 11.—Life cycle of the Angoumois grain moth on wheat.

EUROPEAN GRAIN MOTH

The European grain moth (*Nemapogon granella* (L.)) (fig. 12) is a small moth about the size of the Angoumois grain moth, creamy white and thickly mottled with brown. The mottled appearance distinguishes it from the Angoumois grain moth. It infests all kinds of grain, both in the field and in storage. The larva feeds on the grain and webs the kernels together.

This moth is distributed throughout the Northern States but is not very abundant and cannot be compared with the Angoumois grain moth for destructiveness.

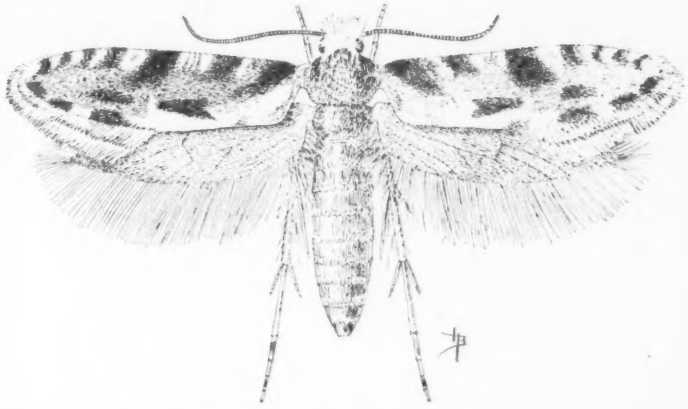

FIGURE 12.—Adult of the European grain moth (*Nemapogon granella* (L.)). The moth has a wing expanse of about one-half inch.

PINK CORNWORM

The pink cornworm (*Pyroderces rileyi* (Wals.)) (fig. 13) is the larva, or caterpillar, of a small moth. It is about five-sixteenths of an inch long when full-grown; pink, with head and thoracic shield pale brown. The moth which develops from this worm or larva is smaller than the Angoumois grain moth, with a wing expanse of slightly less than half an inch. The forewings are banded and mottled with yellow, reddish brown, and black. The pale grayish hindwings are very slender and are edged with long fringes (fig. 14).

This insect is common in the South, where it causes considerable injury to corn, both in the field and in storage. Infestation begins in the field and is continued after the corn is placed in storage. The very characteristic injury is shown in figure 15. The large amount of

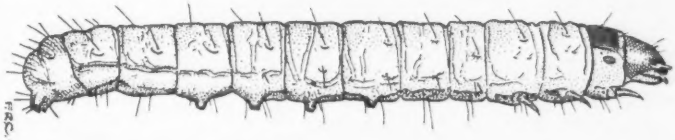

FIGURE 13.—The pink cornworm: Full-grown larva, side view, greatly enlarged. When full-grown, the larva is about five-sixteenths of an inch long.

frass that is loosely webbed together and fills the interstices between the kernels or is crowded into the cavities of kernels that have been eaten out is a reliable indication of the presence of this pest. The pearly white eggs are laid singly or occasionally in twos or threes. The pinkish larvae feed on the seed, husk, and cob with equal relish. Though capable of serious injury to corn, in particular as it comes to maturity in the field and while in the cribs on southern farms, the pink cornworm is seldom a serious pest of commercial shipments.

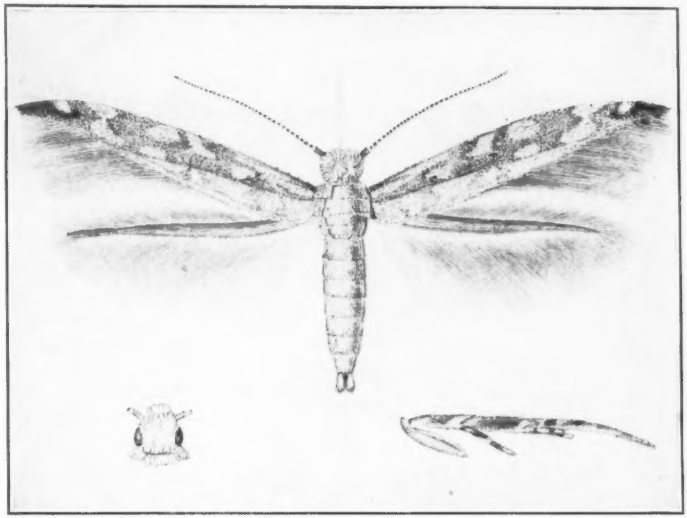

FIGURE 14.—The pink cornworm: Moth, much enlarged; head and leg more enlarged. The moth has a wing spread of a little less than half an inch.

RICE MOTH

The rice moth (*Corcyra cephalonica* (Staint.)) has a wing expanse of about half an inch and is pale grayish brown or tawny. Its characteristic appearance is shown in figure 16. The larva (fig. 17) resembles somewhat that of the Indian-meal moth, being, when full grown, about half an inch long and varying from white to a dirty, slightly bluish gray with occasional tints of green. Damage by the pest, as in the case of all moth pests, is done by the larvae, which are rather general feeders. They attack such materials as rice, cocoa, chocolate, dried fruit, biscuits, and seeds. The larvae produce a dense webbing as they become full-grown. When feeding upon grains, they spin dense silken tubes, webbing the grain kernels into the walls of the tubes. The moths live from 1 to 2 weeks, the females laying between 100 and 200 eggs each. In summer, development from egg to adult covers a period of about 6 weeks. The rice moth has not as yet become very widely disseminated in this country.

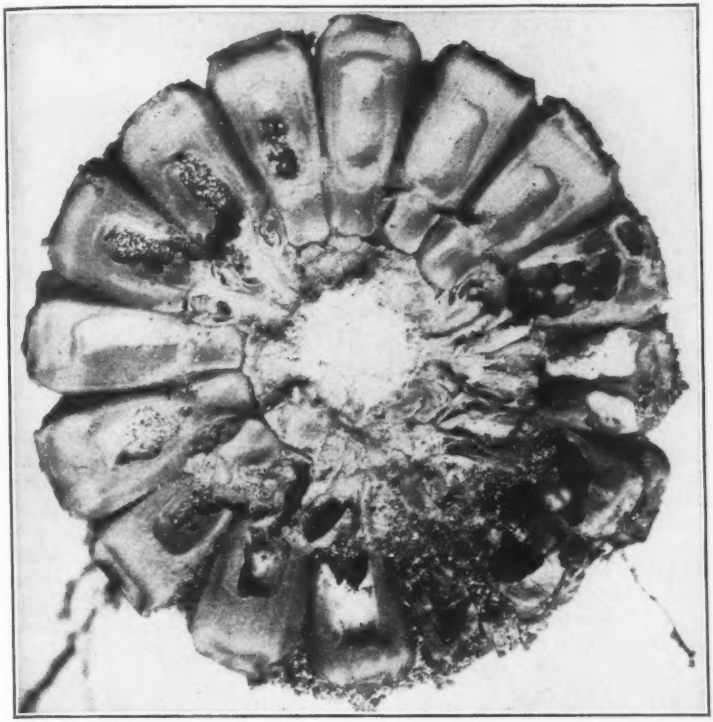

FIGURE 15.—Ear of corn cut to show characteristic feeding and destruction by pink cornworm larvae. Note that the larvae eat from one kernel to another, often severing the kernels from the cob. The larvae sometimes eat into the cob, and there transform to the pupal stage. The pupae are about one-third as long as the kernels shown.

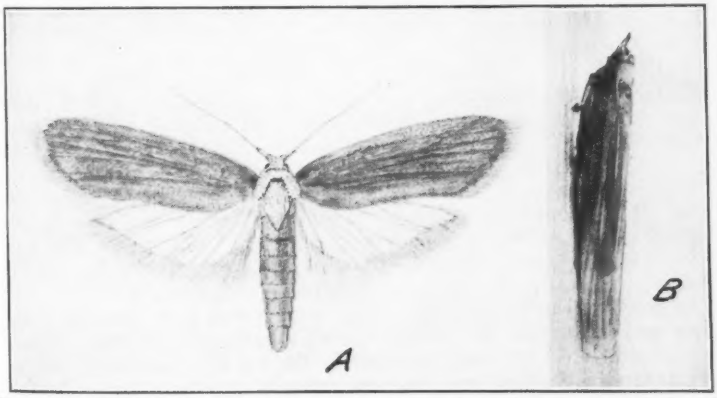

FIGURE 16.—The rice moth: *a*, Mature moth, dorsal view, with wings spread; *b*, side view of same moth with wings folded about body. The moth has a wing spread of about half an inch.

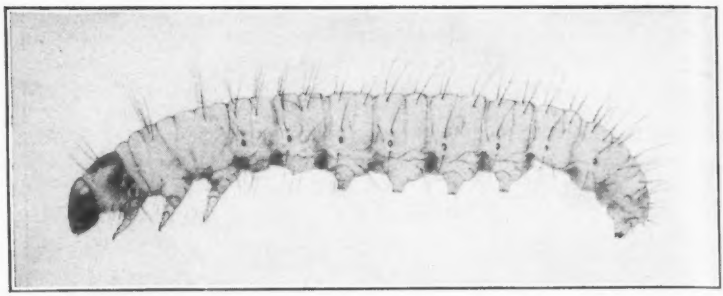

FIGURE 17.—Full-grown larva of the rice moth. The full-grown larva is about one-half inch long.

FLOUR MOTHS

Among the flour moths are some of the commonest and most serious pests of grain products. They are designated as flour moths, not because they feed entirely upon flour or milled products, but because they seldom attack sound kernels. They prefer broken grains, grains injured by major grain pests, and more especially cereal milled products such as flour, breakfast foods, and meals. All three of the flour moths are commonly found in grain warehouses, but the Indian-meal moth and the meal moth are probably the most frequently reported. These two moths may, under exceptionally favorable conditions, become established in whole grain and other seeds and cause injury, especially by eating out the germ.

INDIAN-MEAL MOTH

The Indian-meal moth (*Plodia interpunctella* (Hbn.)) is a rather handsome moth with a wing expanse of nearly three-fourths of an inch (fig. 18). It is easily distinguished from other grain pests by the peculiar marking of its forewings. These are reddish-brown with a coppery luster on the outer two-thirds, but whitish gray on the inner or body end. The female moths lay from 100 to 300 eggs, singly or in groups, on food material. The eggs hatch within a few days into small whitish larvae or caterpillars. These larvae feed upon grains, grain products, dried fruits, nuts, and a rather wide variety of foodstuffs. When full-grown, the larvae are about half an inch long, dirty white, varying sometimes to greenish and pinkish hues. A full-grown larva is shown in figure 19, clinging to a kernel of wheat. This larva spins a silken cocoon and transforms to a light-brown pupa, from which the parent moth later emerges. The Indian-meal moth may pass through its egg, larval, and pupal stages in from 6 to 8 weeks during warm weather.

The larva of the Indian-meal moth spins a web as it becomes full-grown and leaves behind a silken thread wherever it crawls. When sacks of cracked corn, meal, or corn in the ear that has been previously injured by other pests become heavily infested, this webbing often is sufficiently abundant to attract attention. The loosely clinging web shown on the ear of corn in figure 20 is characteristic of this pest.

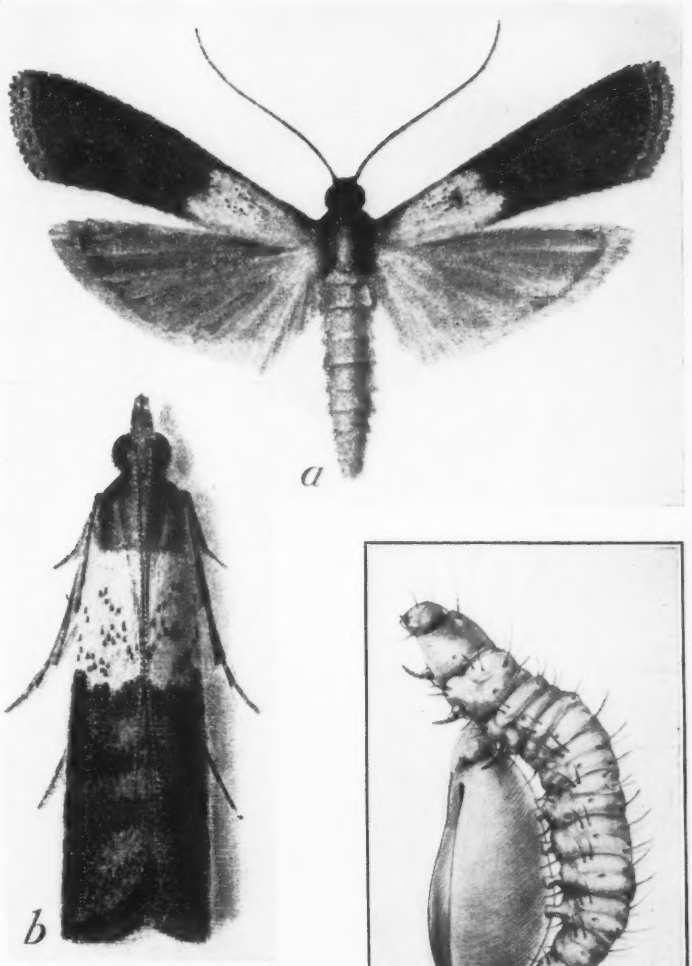

FIGURE 18. — The Indian-meal moth: *a*, Moth with wings spread; *b*, moth with wings folded as ordinarily seen when the moth is resting on some surface in the warehouse. The moth has a wing expanse of nearly three-fourths of an inch.

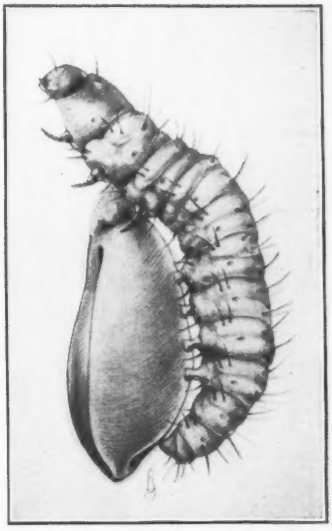

FIGURE 19.—Well-grown larva of the Indian-meal moth, crawling on kernel of wheat.

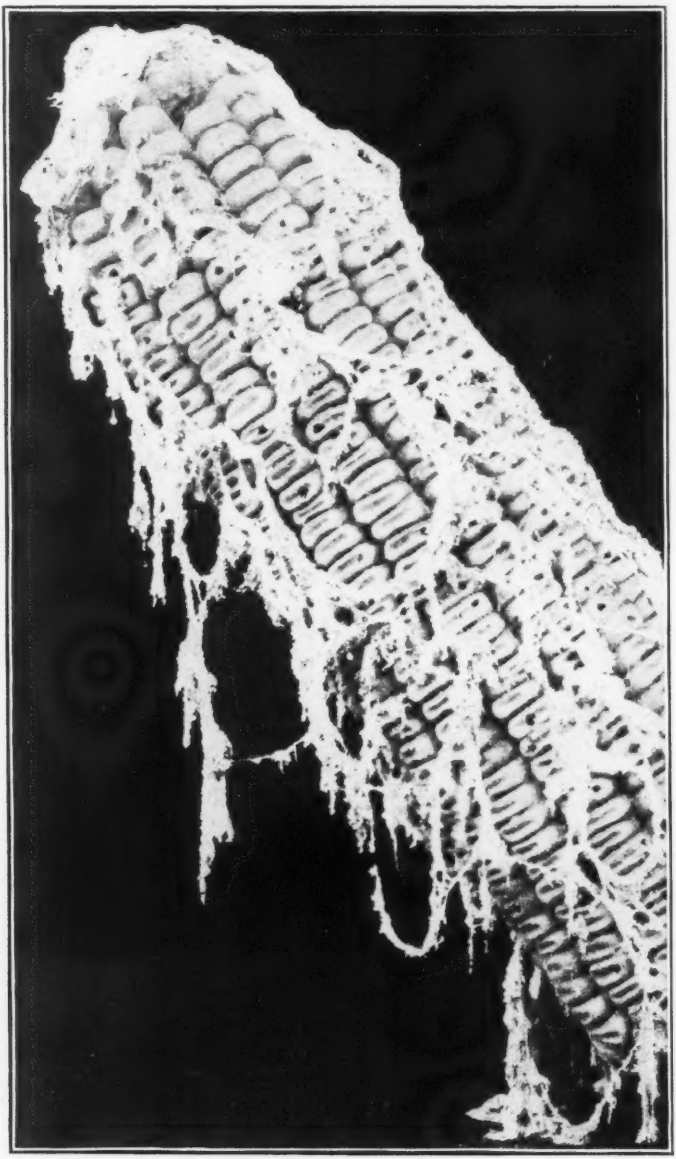

FIGURE 20.—Ear of corn showing the characteristic loose webbing left by larvae of the Indian-meal moth. This moth rarely attacks sound grain, but, as is here shown, frequently attacks grains already injured by other grain pests. Such webbing as is here shown develops only when corn or other grains are left unmoved for some time.

MEDITERRANEAN FLOUR MOTH

The Mediterranean flour moth (*Ephestia kuehniella* Zell.), has a wing spread of slightly less than 1 inch. Its hind wings are a dirty white, but its forewings, which alone show when the moth is not flying, are a pale leaden gray with transverse wavy black markings (fig. 21).

The Mediterranean flour moth is a native of Europe. Its first discovery in the United States was in California in 1892. Since that time it has become widespread over the country and for many years was considered the most troublesome pest of flour mills. The larvae spin silken threads wherever they go, webbing and matting together particles of food in which they are feeding. In flour mills, the machinery sometimes becomes so clogged with the matted flour that milling operations are halted. In mills that have an annual fumigation this insect is no longer a major problem. Although preferring flour and meal, the Mediterranean flour moth attacks grain, bran, cereal products, and many other foodstuffs.

The female moth lays small white eggs in accumulations of flour, meal, or waste grain. From the eggs the small larvae hatch in a few days. When full-grown, these are about half an inch long and are whitish or pinkish, with a few small black spots on the body. The full-grown larva spins a silken cocoon in which the insect transforms to a reddish-brown pupa. Later, the parent moth emerges from the pupa. During warm weather the Mediterranean flour moth requires 8 or 9 weeks to pass through its egg, larva, and pupal stages.

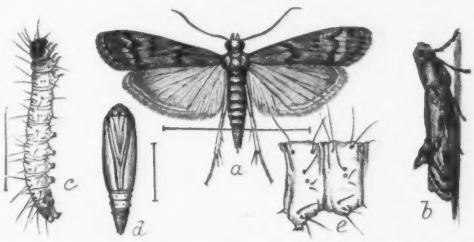

FIGURE 21.—The Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa (enlarged); *e*, abdominal joint of larva (more enlarged). The adult moth has a wing expanse of a trifle less than 1 inch.

Three related species, *Ephestia cautella* (Walk.), *E. elutella* (Hbn.), and *E. figulilella* Gregs., closely resemble the Mediterranean flour moth in appearance and have similar habits. They are general feeders on dried vegetable products, but are rarely abundant enough to cause serious damage to stored cereal products.

MEAL MOTH

The meal moth (*Pyralis farinalis* L.), is brownish and somewhat larger than the Indian-meal moth, though varying in size, usually having a wing spread of about 1 inch. Its forewings are marked in a characteristic pattern, indicated in figure 22; they are light brown with dark-brown patches at the base and tip, and each has two wavy transverse white lines. The meal moth is widely distributed and is a general feeder in the larval stage upon cereals, cereal products, hay, and many types of dried vegetable matter. It is usually

found in damp basements or in other places where accumulations of damp, spoiled grain, bran, or meal are found. While preferring material that is damp and in poor condition, the meal moth may attack and severely damage sound wheat or cereal products if these are stored in moist places or have a relatively high moisture content. This insect sometimes attracts much attention because of its capacity to web up and bind together seeds of various kinds. The larvae cut through burlap sackings and can damage sacks greatly when heavy infestations develop in sacked material. Figure 23 shows the characteristic webbing together of infested seeds—in this instance navy beans—and figure 24 shows the tendency for larvae to spin their

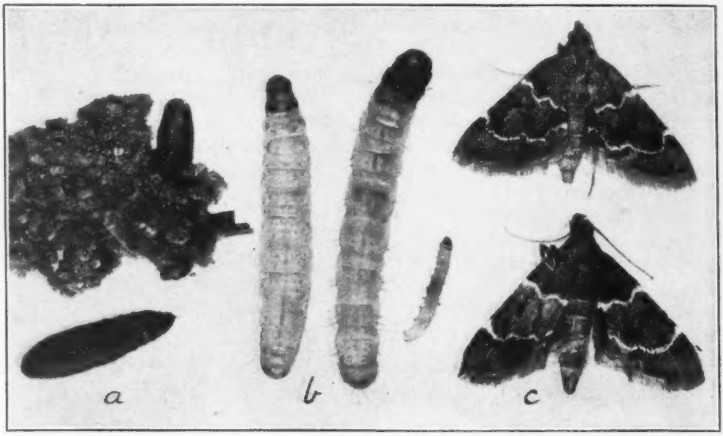

FIGURE 22.—The meal moth: *a*, Pupa and (above) webbed mass of grain showing portion of a pupa protruding; *b*, two well-grown larvae with a smaller larva at right; *c*, two adult moths. Magnified about one and one-half times. The markings on the forewings easily distinguish this insect from other grain pests.

whitish silken cocoons on the outside of grain sacks where the sacks touch one another. When the larvae cut sacks, the seeds fall out and lodge where the sacks touch one another. In such places the seeds are usually heavily infested.

The larvae are whitish and, when full-grown, attain a length of about 1 inch. The two larger larvae in figure 22 indicate the normal shape and show the contrast between the black of the head and the first body segment and the white of the remainder of the body. Often the body of the larva is tinged with orange toward each end. The larvae spin peculiar tubes of silk in which are mixed particles of the food material. They rest in these tubes, which are very tough, and feed from the openings at the ends. When full-grown, the larvae leave the tubes, spin silken cocoons, also often covered with food particles, and transform to the pupae, from which later emerge the adult moths. The female moths live for about a week and lay between 200 and 400 eggs. The developmental period from egg to adult in summer requires from 6 to 8 weeks.

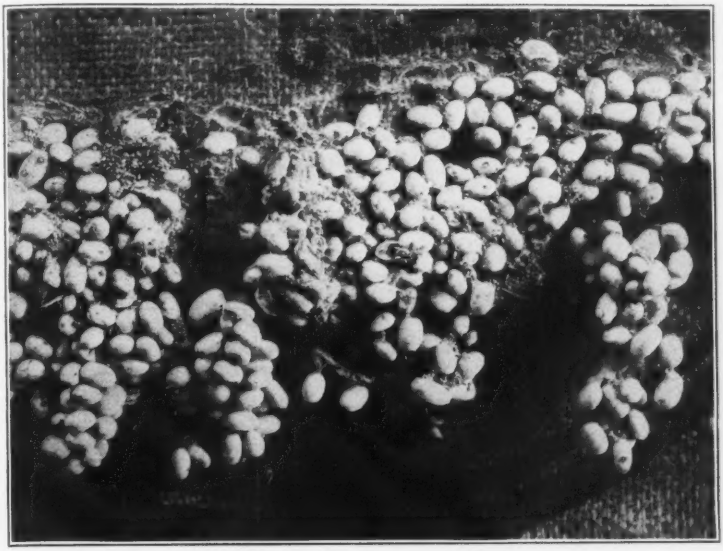

FIGURE 23.—Navy beans webbed together by larvae of the meal moth and adhering to sack.

FIGURE 24.—The outside of a grain sack that was filled with infested vetch seed. Note vetch seed sticking to the side of the bag as a result of the webs of the larvae of the meal moth, the numerous whitish cocoons with dark pupae within, and, in the center, one adult moth. Natural size.

GRAIN AND FLOUR BEETLES

CADELLE

The cadelle (*Tenebroides mauritanicus* (L.)) is an elongate, oblong, flattened, black or blackish beetle about one-third of an inch long (fig. 25). It is sometimes called the bolting-cloth beetle because of its habit of cutting the silk cloths of bolting reels and redressing machines in flour mills.

The larva of the cadelle is one of the largest of the grain-infesting insects and is easily recognized. It is about three-fourths of an inch long, fleshy, with the abdomen terminating in two dark horny points. The larva is a dirty or chalky white, with head, thoracic shield, and the two horny points at the end of the body black.

FIGURE 25.—The cadelle. This beetle is about one-third of an inch long.

This insect is widespread over the world and is frequently found in mills, granaries, and storehouses, where it infests flour, meal, and grain. Both larva and adult feed on grain and have the destructive habit of going from kernel to kernel and devouring the germ. The cadelle is one of the longest-lived of the insects that attack stored grain; many of the adults live for more than a year and some of them for nearly 2 years. The female beetles oviposit during the greater part of their lives and under favorable conditions will lay about 1,000 eggs each.

The white eggs are laid in clusters in the food material and hatch in from 7 to 10 days in warm weather. The larvae complete their growth in from 2 to 14 months, then seek some secluded place in which to transform to the pupal stage (fig. 26), frequently boring into the timbers of the bin or other receptacle that holds the infested material. Both larvae and adults can live for considerable periods without food, frequently remaining hidden in the woodwork of the bins for a long time after the grain has been removed. When new grain is put into such a bin it becomes infested in a surprisingly short time.

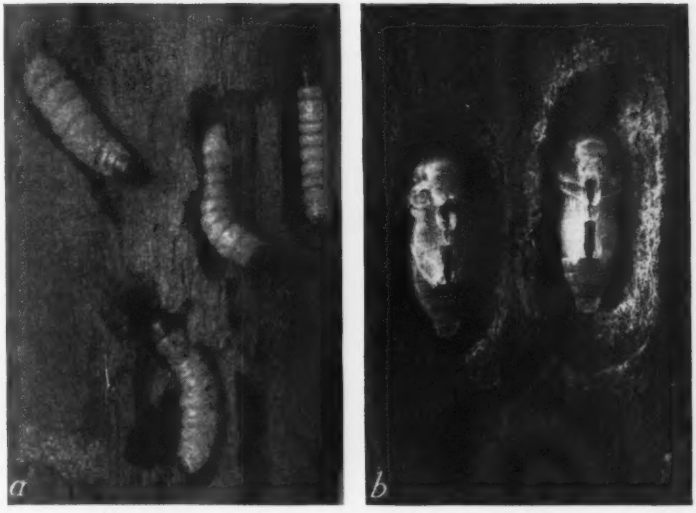

FIGURE 26.—Larvae and pupae of the cadelle: The larvae (*a*) are shown in the galleries they have made in a piece of timber, and the pupae (*b*) in cells hollowed out where two boards were in contact.

SAW-TOOTHED GRAIN BEETLE

The saw-toothed grain beetle (*Oryzaephilus surinamensis* (L.)) is one of the best-known of the cosmopolitan grain pests. A slender, flat, brown beetle about one-tenth of an inch long, it gains its name from the peculiar structure of the thorax, which bears six saw-tooth-like projections on each side (fig. 27). It attacks in both its larval and adult stages all food of vegetable origin, especially grain and such grain products as flours, meals, breakfast foods, stock and poultry feeds, copra, nut meats, candies, and dried fruits.

The adults live, on an average, from 6 to 10 months, but some individuals may live as long as 3 years. The female beetles have been known to lay from 43 to 285 eggs, dropping them loosely among the foodstuff or tucking them away in a crevice in a kernel of grain. The small, slender, white eggs hatch in from 3 to 5 days. The emerging larvae do not spend their lives within a single grain, but crawl about actively, feeding here and there. They become full-grown (fig. 27, *a*) in about 2 weeks during summer weather and then construct delicate cocoonlike coverings by joining together small grains or fragments of foodstuffs with a sticky secretion. Within this cell the larva changes to the pupal stage, which lasts about a week. Development from egg to adult may take place in from 3 to 4 weeks in summer.

Two closely related species occur in this country, *Oryzaephilus bicornis* (Er.), and the merchant grain beetle (*O. mercator* (Fauv.)). They closely resemble the saw-toothed grain beetle in appearance and habit and are easily confused with it. The first-named differs from *surinamensis* chiefly in that the side margins of the front in the male are more strongly reflexed, forming promi-

nent, pointed, earlike horns. *O. mercator* differs in appearance from *O. surinamensis* chiefly because of much narrower, more sharply projecting temples.

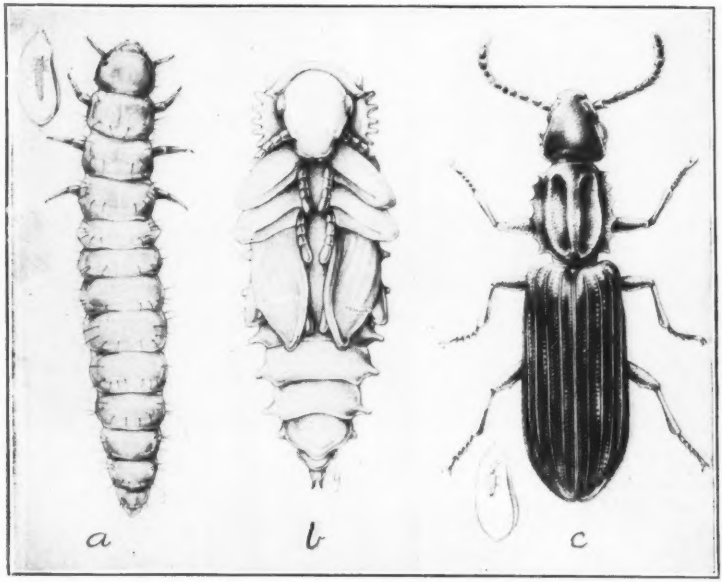

FIGURE 27.—The saw-toothed grain beetle: *a*, Well-grown larva; *b*, pupa; *c*, adult beetle. The adult beetle is about one-tenth of an inch in length. Beside the larva and adult are shown grains of wheat with the relative size of the insect indicated on them.

SQUARE-NECKED GRAIN BEETLE

The square-necked grain beetle (*Cathartus quadricollis* (Guér.)), is closely related to the saw-toothed grain beetle, which it greatly resembles in form, size, and color. It is a flattened, oblong, polished, reddish-brown beetle about one-tenth of an inch long. It differs from the saw-toothed grain beetle by having the thorax almost square and in lacking the saw-toothlike projections (fig. 28).

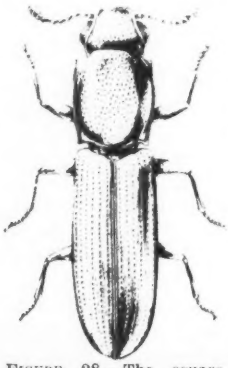

FIGURE 28.—The square-necked grain beetle. The adult beetle is about one-tenth of an inch long.

This beetle is chiefly abundant in the South, where it is found in great numbers outdoors infesting the seed pods of a great variety of plants. It is one of the most common beetles in stored corn in the South and in the cornfields is always to be found on damaged or exposed ears. The immature stages closely resemble those of the preceding species both in form and in habit. The larvae have the bad habit of devouring the germ of the seed in which they breed. They can develop from egg to adult in about 3 weeks.

FIGURE 29.—The foreign grain beetle.

FOREIGN GRAIN BEETLE

The foreign grain beetle (*Ahasverus advena* (Waltl.))is a small reddish-brown beetle somewhat similar in appearance to the preceding species, to which it is closely related. It differs from it by being smaller and more robust (fig. 29). Although of world-wide distribution, it is of little consequence as an enemy of stored grains. It is attracted to damp and moldy grains and feeds on the molds developing in such grains. It is rarely found in clean grain.

MEXICAN GRAIN BEETLE

The Mexican grain beetle (*Pharaxonotha kirschi* Reitt.) (fig. 30) is a highly polished, deep-brown beetle about three-sixteenths of an inch long. While resembling somewhat the confused flour beetle in general appearance, it can be readily distinguished by its more polished surface and by its longer antennae.

This insect is common in Mexico and Guatemala, where it breeds in grain and grain products. It was found in this country in grain exhibits at the World's Columbian Exposition but is not known to be permanently established in this country as yet. It may be found in grain in the extreme South.

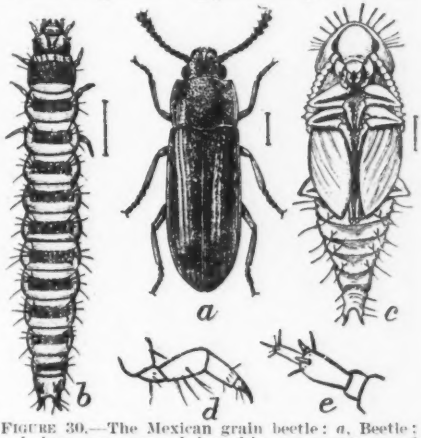

FIGURE 30.—The Mexican grain beetle: *a*, Beetle; *b*, larva; *c*, pupa; *d*, leg of larva; *e*, antenna of larva. *a*, *b*, *c*, enlarged about 8 times; *d*, *e*, greatly enlarged.

SIAMESE GRAIN BEETLE

The Siamese grain beetle (*Lophocateres pusillus* (Klug)) is a flattened, reddish-brown beetle slightly less than an eighth of an inch long, characterized by the much flattened margins of the thorax and wing covers (fig. 31).

First appearing in this country in exhibits of rice and cereals from Siam, Liberia, and Ceylon at the World's Columbian Exposition, it is now well-established in the Southern States. It is commonly found in rice mills in Texas but does not cause serious damage.

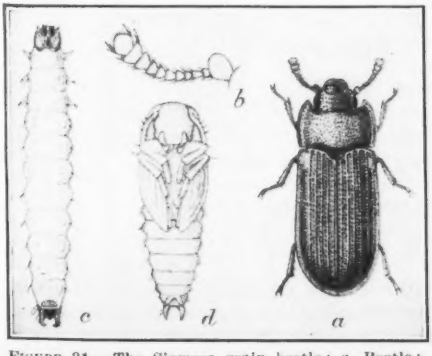

FIGURE 31.—The Siamese grain beetle: *a*, Beetle; *b*, antenna of same; *c*, larva; *d*, pupa. *a*, *c*, *d*, about 10 times natural size; *b*, about 30 times natural size.

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FLAT GRAIN BEETLE

The flat grain beetle (*Laemophloeus minutus* (Oliv.)) (fig. 32), as its scientific name would indicate, is one of the smallest beetles commonly found in stored grain. It is a minute, flattened, oblong, reddish-brown beetle about one-sixteenth of an inch long, with elongate antennae about two-thirds as long as the body. It is cosmopolitan in distribution and is one of the commonest insect pests of stored grain. It is not a primary pest of stored grain, however, and the adult is apparently unable to survive in sound, uninjured grain. It follows up the attack of the more vigorous grain pests and is frequently found in enormous numbers associated with the rice weevil. It is a scavenger by nature and often infests grain and meal that is out of condition.

FIGURE 32.—Adult of the flat grain beetle, showing characteristic long antenna. Body not more than one-sixteenth of an inch long.

The small white eggs are placed in crevices in the grain or dropped loosely in farinaceous material. The larvae are particularly fond of the germ in wheat, and in infested grain many kernels will be found uninjured except for the removal of the germ. The larvae also feed on dead insects. When fully grown, the larvae form cocoons of a gelatinous substance to which food particles adhere. They transform to the pupal stage in these cocoons and later emerge as adults. Under favorable conditions this insect may complete its development from egg to adult in about 5 weeks, although the average length of the developmental period in summer is about 9 weeks.

A related beetle, *L. turcicus* Grouv., resembles the preceding species so closely in appearance and habit that it is usually confused with it. It also is cosmopolitan in distribution. The females of the two species are so much alike that it is almost impossible to distinguish between them. The males, however, can be distinguished by the length of the antennae. In *L. turcicus* the antennae of the male beetles are as long as or longer than the body, whereas in *L. minutus* the antennae of the males are only two-thirds the length of the body.

RUST-RED GRAIN BEETLE

A third species, *Laemophloeus ferrugineus* (Steph.), known as the rust-red grain beetle, is similar to the two preceding species in appearance and habit, but differs in that the antennae of the male beetle are not more than half as long as the body. This species is more resistant to cold weather than the other two species and is more commonly found in stored grain in the Northern States.

CONFUSED FLOUR BEETLE

The confused flour beetle (*Tribolium confusum* Jacq.-Duv.) (fig. 33) is a shiny, reddish-brown beetle about one-seventh of an inch long, flattened and oval, with head and upper parts of thorax densely covered with minute punctures and with wing covers ridged lengthwise

and sparsely punctured between the ridges. It is generally distributed over the world and is very abundant in all parts of this country. It is a general feeder on farinaceous material and is undoubtedly the most abundant and injurious insect pest of flour mills in the United States. It is found in granaries, mills, warehouses, and everywhere where grain or grain products are stored.

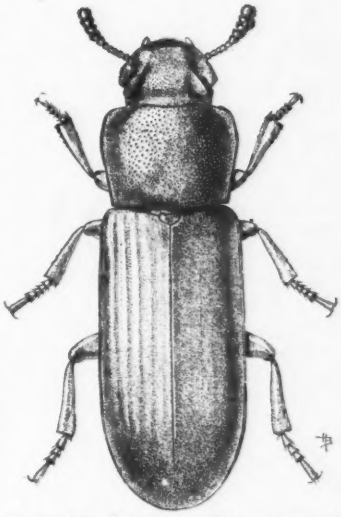

FIGURE 33.—The confused flour beetle is undoubtedly more troublesome in flour mills than any other insect except the closely related rust-red flour beetle. The beetle is about one-seventh of an inch long.

The average life of the beetles is about 1 year, but some have been known to live as long as 3 years 9 months. The females lay an average of about 450 eggs each. The small white eggs are laid loosely in flour or other food material in which the adults are living. They are covered with a sticky secretion and thus become covered with flour or meal, and readily adhere to the sides of sacks, boxes, and other containers, so that fresh material placed in them is rapidly infested. The eggs hatch in from 5 to 12 days into small wormlike larvae, slender, cylindrical, and wiry in appearance. When fully grown they are about three-sixteenths of an inch long, and are white, tinged with yellow. These larvae feed on flour or other material such as grain dust and the broken surfaces of grain kernels. When full grown they transform to small naked pupae. At first white, the pupae gradually change to yellow and then brown, and shortly afterwards transform to beetles. The period from egg to adult in summer averages about 6 weeks under favorable weather conditions, though the life cycle is greatly prolonged by cold weather, as is true of all grain pests.

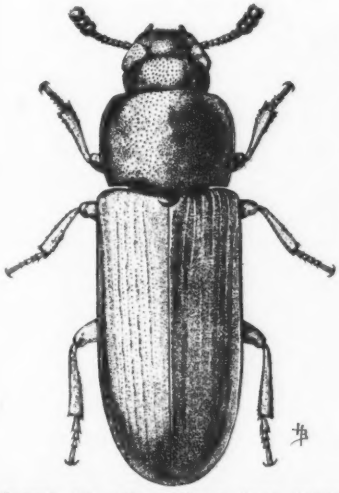

FIGURE 34.—The rust-red flour beetle. The beetle is about one-seventh of an inch long.

RUST-RED FLOUR BEETLE

The rust-red flour beetle (*Tribolium castaneum* (Herbst)) is almost identical in appearance with the preceding species, to which it is closely related. It can be distinguished from the confused flour beetle only with the aid of a mag-

nifying glass. The segments of the antennae of the confused flour beetle increase in size gradually from the base to the tip, whereas in the rust-red flour beetle the last few segments of the antennae are abruptly much larger than the preceding ones, giving the antennae the appearance of being suddenly enlarged at the tip. In addition, the margins of the head of the confused flour beetle are expanded and notched at the eyes, whereas the margins of the head of this species are nearly continuous at the eyes. The differences between the two species are clearly shown in figures 33 and 34. This insect is constantly found associated with the confused flour beetle and has similar feeding and breeding habits. The immature stages of the two insects are so nearly alike that it is impossible to distinguish between them. The developmental period from egg to adult is usually somewhat shorter than for the preceding species. Although cosmopolitan in distribution, the rust-red flour beetle is found more commonly in the South, where it causes very serious damage to grain products. In addition to the actual damage caused by its feeding activities, it imparts a nauseous smell and taste to the material it infests. Like the confused flour beetle, the rust-red flour beetle is primarily a pest of milled products; while present in grain shipments, it confines its attack in these to grain dust and the surface of broken grains, hence is not a primary pest of commercial shipments.

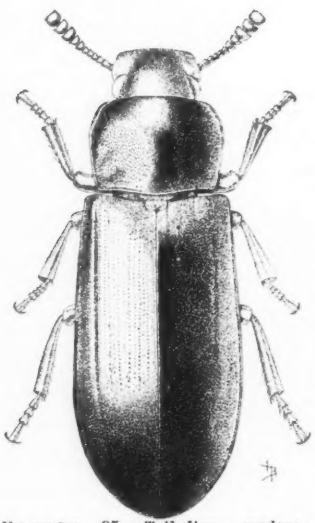

FIGURE 35.—*Tribolium madens:* Adult. The beetle is about one-sixth of an inch in length.

BLACK FLOUR BEETLE

The black flour beetle (*Tribolium madens* (Charp.)) (fig. 35), is another species of the genus *Tribolium* that occurs in the United States. Not so well known as the two preceding species, it has similar habits and is occasionally found infesting grain and grain products in flour mills and storehouses. It is seldom found in injurious numbers and is by no means as widespread as *T. confusum* and *T. castaneum*. It occurs in its greatest abundance in the States of the Rocky Mountain region, but it has been reported from widely scattered points over the country. It may be readily distinguished from the confused and rust-red flour beetles by its being black and by its larger size. It is about one-sixth of an inch in length. *T. destructor* Uyttenb., another species of this destructive group of flour beetles, has recently been reported from Montreal, Canada, infesting poultry feed. It is an introduction from Europe.

LONG-HEADED FLOUR BEETLE

The long-headed flour beetle (*Latheticus oryzae* Waterh.) (fig. 36) is a slender, flattened beetle, slightly less than an eighth of an inch long, somewhat similar in form to the confused flour beetle but narrower and pale yellowish brown. It is further differentiated by the peculiarly shaped antennae and by the minute canthus behind each eye. It has been reported from most parts of the world as infesting wheat, rice, corn, barley, rye flour, and similar products. It was first recognized in this country from specimens collected in Texas in 1908. It is now widespread in the Southern and Middle Western States, where it is common in rice and flour mills, infesting grain and grain products and causing the same type of damage as does the confused flour beetle.

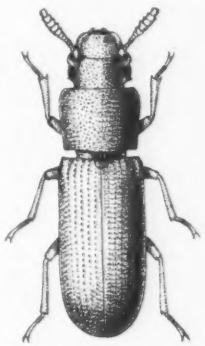

FIGURE 36.—Long-headed flour beetle. The beetle is slightly less than one-eighth of an inch long.

BROAD-HORNED FLOUR BEETLE

The broad-horned flour beetle (*Gnathocerus cornutus* (F.)) owes its name to the peculiar structure of the mandibles, or jaws, of the male beetle, which are armed with a pair of broad, stout horns, as shown in figure 37. It is a robust, reddish-brown beetle, about one-sixth of an inch long, closely resembling the other flour beetles in appearance, but easily distinguished by the peculiar structure of the jaws. It is cosmopolitan in distribution and is common in

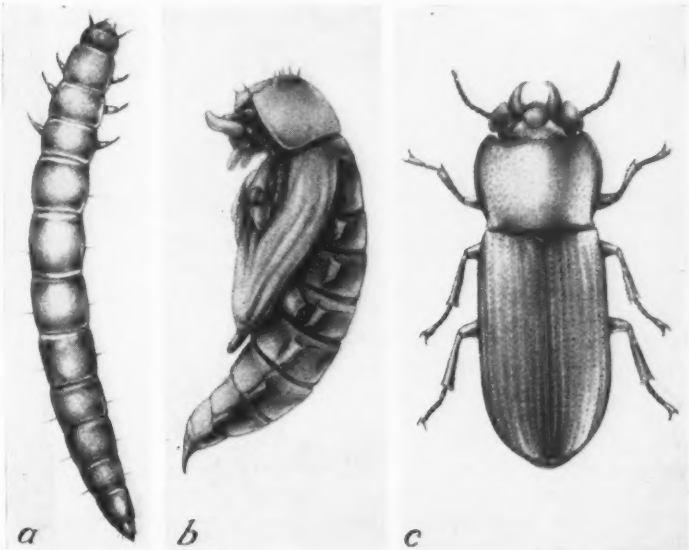

FIGURE 37.—The broad-horned flour beetle: *a*, Larva; *b*, pupa; *c*, adult. The beetle is about one-sixth of an inch long.

all parts of the United States except in the Great Plains, where it is comparatively rare. It prefers to feed in flour and meal, but is found in a variety of grains. The adult beetles frequently live for a year or longer, the females laying from 100 to 200 eggs each. The small white eggs hatch in from 4 to 6 days in warm weather, and development from egg to adult takes place in from 6 to 8 weeks.

SLENDER-HORNED FLOUR BEETLE

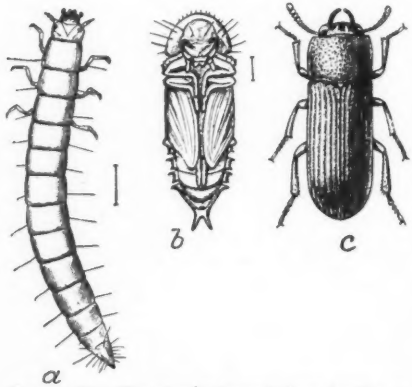

FIGURE 38.—The slender-horned flour beetle: *a*, Larva; *b*, pupa; *c*, beetle. The beetle is about one-eighth of an inch long.

The slender-horned flour beetle (*Gnathocerus maxillosus* (F.)) is closely related to the preceding species and is of similar form and appearance. It is about one-eighth of an inch in length, and, in addition to its smaller size, it may be distinguished from the broad horned flour beetle by the shape of the horns with which the mandibles or jaws of the male are armed. In this species (fig. 38) the horns are slender and incurved. Its habits are similar to those of the preceding species. It is less common in the United States than *G. cornutus* and is more or less confined to the Southern States.

SMALL-EYED FLOUR BEETLE

FIGURE 39.—The small-eyed flour beetle. The beetle is about one-tenth of an inch long.

The small-eyed flour beetle (*Palorus ratzeburgi* (Wissm.)) (fig. 39), is the smallest of the so-called flour beetles that infest grain and grain products in this country. It is a tiny, flattened, shiny, reddish-brown beetle, somewhat oblong in form and measuring about one-tenth of an inch in length. It occurs throughout the world and is widely distributed in this country. It breeds in grain and milled products and is frequently found in flour-mill basements.

DEPRESSED FLOUR BEETLE

The depressed flour beetle (*Palorus subdepressus* Woll.) is very similar in appearance and habits to the small-eyed flour beetle. It may be distinquished from this species by its slightly larger size and by the fact that the sides of the front of the head are strongly reflexed and extend backward, concealing the front portion of the eye. In the small-eyed flour beetle the sides of the front do not extend backward. The depressed flour beetle, also, is cosmopolitan in distribution but is much less common in the United States than *P. ratzeburgi* except perhaps in the Great Plains.

EGGS OF FLOUR AND GRAIN INSECTS

The eggs of the common flour- and grain-infesting insects are rarely seen by the layman. They are usually white in color and are often covered with a sticky substance that causes particles of flour or other material to adhere to them, thus making them difficult to distinguish from the foodstuff in which they are deposited. Some are oval or oblong-oval, while others are slender and spindle shaped. Their small size is well illustrated in figure 40, in which is shown a group of eggs of four different species of insects resting on a piece of 10XX silk bolting cloth. The eggs of the flat grain beetle are so small that if placed side by side they would average about 150 to the inch. Those of the cadelle, which is one of the larger beetles infesting stored cereal products, if laid end to end, would average about 19 to the inch. During the process of milling flour and preparing it for the market it is sifted through silk bolting cloth to remove insect eggs and other impurities.

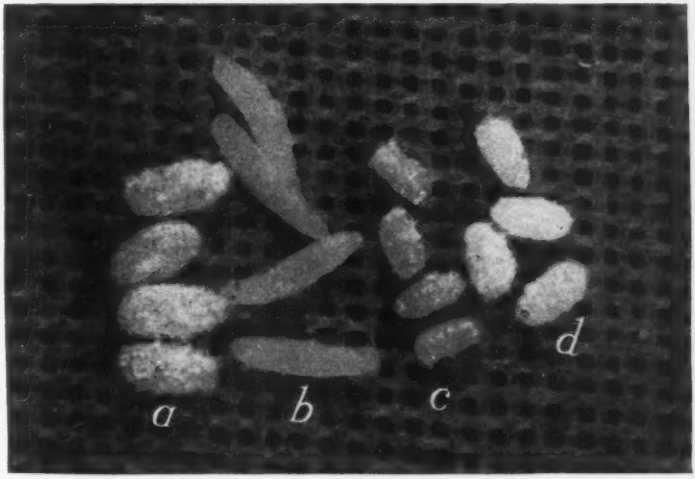

FIGURE 40.—Eggs of flour and grain insects shown resting on a piece of 10XX bolting cloth: *a*, Broad-horned flour beetle; *b*, cadelle; *c*, Mediterranean flour moth; *d*, confused flour beetle. Magnified 20 diameters.

MEALWORMS

The term "mealworm" is applied to the larvae of several beetles of the family Tenebrionidae that are nocturnal in habit and frequent dark places. They breed in refuse grain and coarse cereal and mill products that accumulate in dark corners, under sacks, in bins, and in similar places. They are fond of moist situations and are often found among bags that are slightly damp.

YELLOW MEALWORMS

The yellow mealworm (*Tenebrio molitor* L.) is one of the largest of the insects that infest stored cereal products. It is cosmopolitan in distribution, but, although found occasionally in all parts of the country, it is found in abundance only in the Northern States.

The adult is a polished dark-brown or black beetle, somewhat more than half an inch long, with its thorax finely punctured and with its wing covers longitudinally striated or grooved. The females lay bean-shaped white eggs covered with a sticky secretion that causes the flour, meal, or grain waste in which they are placed to adhere to them. The eggs hatch in about 2 weeks into slender white larvae, which soon turn yellow and assume the form shown in figure 41. When full-grown, the larvae are about an inch long and yellowish, shading to yellowish brown toward each end and at the articulation of each segment. It is to the yellow color of the larva that this insect owes its name of "yellow mealworm."

There is but one generation each year. The adults begin to appear in the latitude of Washington, D. C., in the latter part of May and early in June and may be found until late in August. The female beetles are quite prolific and may lay as many as 500 eggs each. The larvae become full-grown in about 3 months, but instead of transforming then to the adult stage they continue feeding and molting until cold weather and then hibernate as larvae. In late spring or early summer of the following season they transform to the pupal stage, in which stage the insect passes about 2 weeks. Because the yellow mealworm has but one generation each year and is entirely an external feeder upon grains, it need not be feared as a

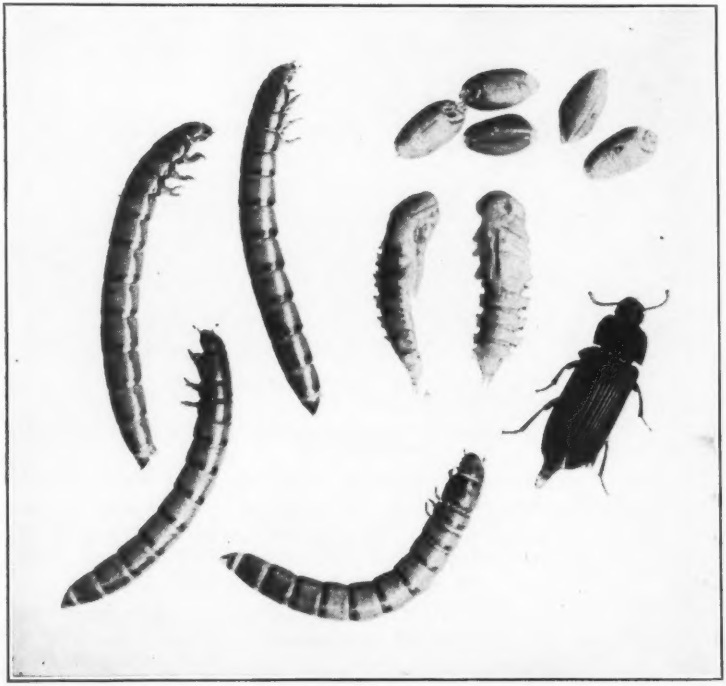

FIGURE 41.—The yellow mealworm. Four well-grown larvae, two pupae, and the black adult beetle, with five kernels of wheat to indicate relative size. The larvae when full-grown are about 1 inch long and yellowish. The adult beetles are slightly more than half an inch long.

serious pest. Screening and fanning will remove it easily from grain shipments. The well-grown larvae, however, can do serious injury to whole grains under certain conditions when grain is held for long periods without being moved.

DARK MEALWORM

The dark mealworm (*Tenebrio obscurus* F.) is very similar in form, size, and color to the yellow mealworm, to which it is closely related. The adult beetle differs, however, in being dull pitchy black, in contrast to the shiny or polished dark brown or black of the yellow mealworm. Its larva so closely resembles the larva of the yellow mealworm that it can be distinguished most easily by its much darker color.

The two species of mealworms are often found associated, since they have similar feeding habits. The overwintering larvae of the dark mealworm begin to pupate earlier in the season than the yellow mealworms, and the adult beetles emerge during April and May in the vicinity of Washington.

LESSER MEALWORM

The lesser mealworm (*Alphitobius diaperinus* (Panz.)) resembles the two preceding species in form and color but is considerably smaller. It is black or a very dark reddish brown and measures from three-sixteenths to four-sixteenths of an inch in length. The larva is yellowish brown and closely resembles young larvae of the yellow mealworm in form and appearance. It is cosmopolitan in distribution and is commonly found in flour-mill basements in damp or musty flour or grain. It prefers grain and cereal products that are slightly out of condition.

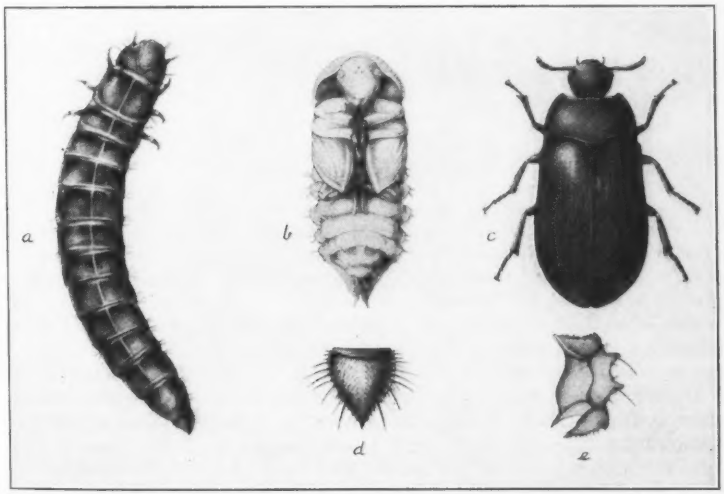

FIGURE 42.—The black fungus beetle: *a*, Larva; *b*, pupa; *c*, adult; *d*, caudal segment of larva; *e*, lateral plate of pupa. The larva is about 1 inch long.

BLACK FUNGUS BEETLE

The black fungus beetle (*Alphitobius piceus* (Oliv.)) (fig. 42) is almost identical in appearance with the lesser mealworm and has similar habits. It prefers grain and cereal products that are damp and moldy and does not cause serious damage to sound grain. It may be distinguished from the preceding species by the fact that the sides of the thorax are curved and the surface coarsely and profusely punctured, whereas in the lesser mealworm the sides of the thorax are nearly straight and the surface finely and sparsely punctured. In the United States it is much less abundant than the lesser mealworm.

DERMESTID BEETLES

The dermestids are a group of beetles that in general are scavengers and feeders on animal matter. Certain species, however, belonging to the genera *Trogoderma*, *Anthrenus*, and *Attagenus* have acquired the habit of varying their diet by feeding at least in part on farinaceous materials. They are of frequent occurrence in flour mills, farm granaries, warehouses, and similar places where grain and grain products are stored.

BLACK CARPET BEETLE

The black carpet beetle (*Attagenus piceus* (Oliv.)) is a small oval beetle between two-sixteenths and three-sixteenths of an inch long. The head and thorax are black, but the wing covers may be either black or dark reddish brown, and clothed with short hairs. Its legs and antennae are dark yellow. The larva is very characteristic and can be readily recognized. It is reddish or golden brown, clothed with short, scalelike, appressed hairs and provided with a tuft of long hairs at the end of the body, as shown in figure 43.

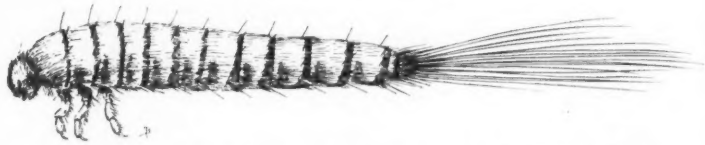

FIGURE 43.—Larva of the black carpet beetle. The larva, including the tuft of hairs, is about two-fifths inch long.

As the name indicates, this insect injures carpets, but in addition it is frequently found infesting stored grain and cereals, both whole and ground. It is usually found associated with other grain-infesting insects, and since it does not thrive on a purely vegetable diet it supplements its diet by occasionally feeding on their dead bodies. The larvae are often to be found in abundance breeding in cracks in the floors of warehouses where foodstuffs have accumulated. In the spring these larvae transform to adults which swarm over bagged material stored there. The larvae of the black carpet beetle develop slowly, so that there is only one generation a year. If conditions are unfavorable the life cycle may be prolonged to 2 or 3 years. The adults which emerge in the spring and early part of the summer live from 2 to 4 weeks, and the females may lay about 100 eggs. It is cosmopolitan in distribution.

LARGER CABINET BEETLE

The larger cabinet beetle (*Trogoderma versicolor* (Creutz.)) is a small, oval beetle about one-eighth of an inch long, its ground color black mottled with reddish brown, covered with gray and light-brown scalelike hairs forming a distinct pattern on the wing covers. The larva somewhat resembles that of the black carpet beetle in appearance. It is about one-eighth of an inch long, reddish brown above and whitish beneath, with body covered with short yellowish-brown hairs and with a tuft of short hairs at the tail end (fig. 44). It is well known for its habit of breeding in dead insects and animal substances and is a serious pest in seed collections. It is one of the few dermestid beetles that seem to thrive on a wholly vegetable diet. The adults are to be found in heated buildings throughout the year. The females may lay as many as 180 eggs, although the average is about 50. The complete life cycle from adult to adult may take about 3 months under favorable conditions. The adults live from 2 to 4 weeks.

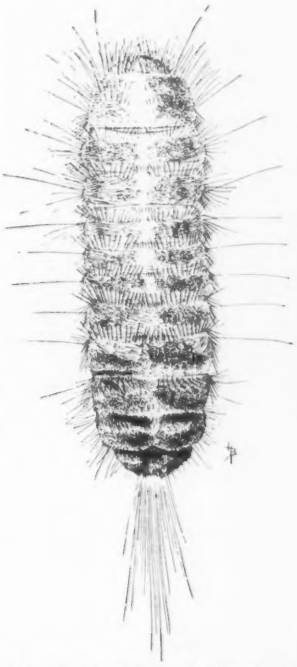

FIGURE 44.—Larva of the larger cabinet beetle. The larva is about one-eighth of an inch long.

VARIED CARPET BEETLE

The varied carpet beetle (*Anthrenus verbasci* (L.)) is somewhat similar in appearance to the larger cabinet beetle but smaller and of different color. It ranges in length from one-sixteenth to two-sixteenths of an inch, and is black with yellowish-white scales that form a broad band across the back and give the body a mottled appearance. The habits of the adult and early stages of this insect are similar to those of the larger cabinet beetle. It is occasionally found in flour mills and granaries, where it infests grain and grain products. The larva is shown in figure 45.

SPIDER BEETLES

Several species of beetles belonging to the family Ptinidae are occasionally found infesting grain and cereal products and attract attention by their peculiar spiderlike form. They are rather widespread in distribution but are rarely abundant enough in the United States to cause serious damage.

HAIRY SPIDER BEETLE

The hairy spider beetle (*Ptinus villiger* (Reit.)) (fig. 46) is a reddish-brown beetle marked with four irregular white patches. It is about one-seventh of an inch long. It is a rather common pest in

the prairie Provinces of Canada and is occasionally destructive in the adjoining Northern States. It attacks stored grain and all types of ground cereal products. The adult beetles appear in warehouses in the spring and lay their eggs in flour, feed, or other cereal products. The female beetles have been observed to lay about 40 eggs. Under favorable conditions development from egg to adult takes place in about 3½ months. The full-grown larvae construct characteristic pupal cases of a silky material covered with particles of the food material in which they occur.

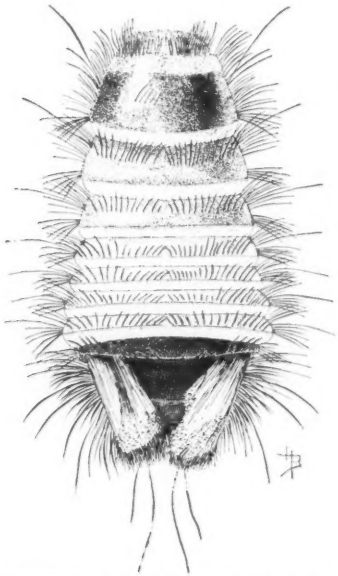

FIGURE 45.—Larva of the varied carpet beetle. The larva is usually about three-sixteenths of an inch long.

BROWN SPIDER BEETLE

The brown spider beetle (*Ptinus brunneus* Dufts.) closely resembles the preceding species in size, color, general appearance, and habits. It may be distinguished from the white-marked spider beetle by the fact that the white markings of the wing covers are lacking.

OTHER SPIDER BEETLES

The Australian spider beetle (*Ptinus tectus* Boield.) has been reported from the United States but is rarely found here. It is very similar in general appearance and habits to the preceding species.

WHITE-MARKED SPIDER BEETLE

The white-marked spider beetle (*Ptinus fur* L.) (fig. 47) is also found in the Northern States and is somewhat more abundant than the preceding species, which it resembles closely in appearance and habits. It is an omnivorous feeder, attacking flour, feed, grain, and miscellaneous foodstuffs. It is rarely abundant enough to cause serious damage.

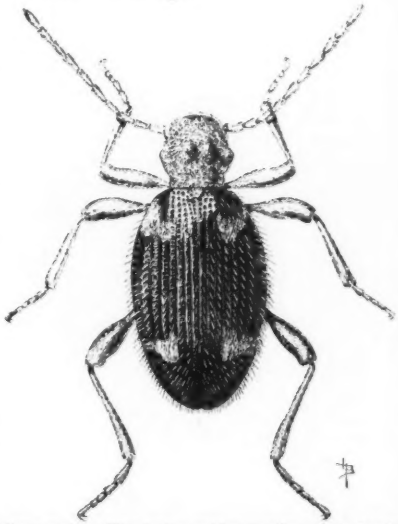

FIGURE 46.—The hairy spider beetle. This beetle is about one-seventh of an inch long.

Mezium americanum (Laporte) (fig. 48) is a small spider beetle of striking appearance. It has a shining subglobular body that distinguishes it from the preceding species. It appears to be somewhat of a scavenger, feeding on dried animal products as well as on organic material. It is not important as a pest of stored grain or grain products, but is occasionally found in mills, warehouses, and dwellings. A closely related species, *Gibbium psylloides* Czemp., resembles it closely in appearance and habits and is found in similar situations. It may be distinguished from it by the fact that the head and thorax are entirely bare while in *M. americanum* the head and thorax are densely covered with small scales and scalelike hairs.

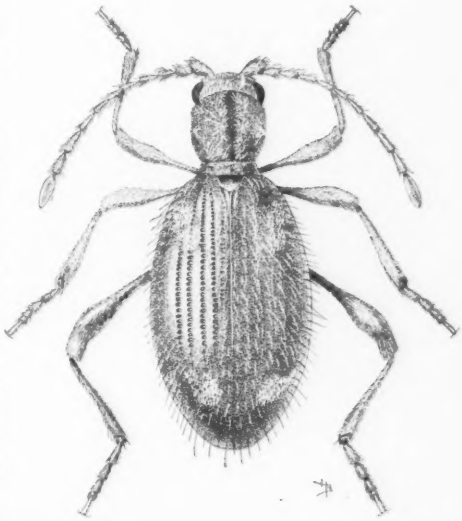

FIGURE 47.—The white-marked spider beetle, adult female. (The male is elongate oval and is not so conspicuously marked as the female.)

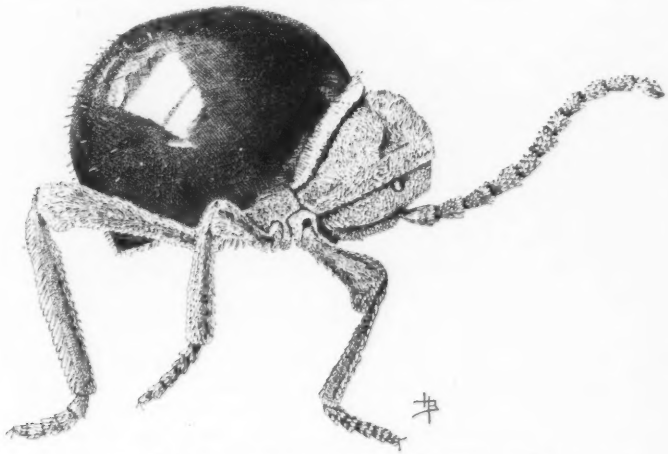

FIGURE 48.—*Mezium americanum*, adult beetle. × 20.

MISCELLANEOUS BEETLES

TWO-BANDED FUNGUS BEETLE

The two-banded fungus beetle (*Alphitophagus bifasciatus* (Say)) is a handsome little elongate-oval beetle slightly less than an eighth of an inch long. It is reddish brown with two broad black bands across the wing covers. Its characteristic color pattern is shown in figure 49. It is distributed over the world and is in general a feeder on fungi and molds, being a scavenger in refuse grain and grain products, decaying vegetable matter, etc. It is frequently found around mills and storehouses where waste material is allowed to accumulate. The larvae have been reared from moist corn meal and in spoiled cereals. The insect is often found in the holds of grain ships in wet or damaged grain.

FIGURE 49.—The two-banded fungus beetle, adult ×10.

CORN SAP BEETLE

The corn sap beetle (*Carpophilus dimidiatus* (F.)) may be readily recognized by its peculiar wing covers, which are short and truncate, leaving the tip of the abdomen exposed, as shown in figure 50. It is a small, dark-brown beetle with lighter colored wing covers, oblong-ovoid in shape, and ranging in length from one-tenth to one-eighth of an inch. It normally feeds in rotting and decaying fruit and vegetation and in the sap exuding from injured plants. It is quite numerous in cornfields in the South, swarming over the damaged ears and feeding and breeding in the decaying kernels. It is attracted to damp and decaying grain and is not infrequently found in rice mills breeding in accumulations of broken rice. It is often seen in swarms crawling over bags of rice.

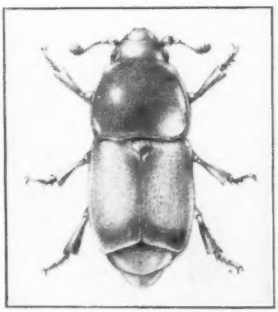

FIGURE 50.—The corn sap beetle, adult. ×15.

A closely related beetle (*Carpophilus humeralis* Murray) that has been introduced from abroad and is becoming more and more abundant is similar in form to the corn sap beetle, but is slightly larger and is uniform, shiny, dark brown all over. Its habits are very similar to those of the preceding species.

CIGARETTE BEETLE

The cigarette beetle (*Lasioderma serricorne* (F.)) is a small, robust, oval, reddish-yellow or brownish-red beetle, with head bent down nearly at right angles to the body, giving the beetle a humped appearance when viewed from the side as shown in figure 51. It varies in size, but is usually about one-tenth of an inch long. It is found in all temperate, subtropical, and tropical regions and infests

tobacco and many other stored products. It breeds in a variety of seeds and may occasionally be found attacking grains left long in storage in original sacks.

The adult beetles live from 2 to 4 weeks, and during this time the females may lay as many as 100 eggs. The developmental period from egg to adult is quite variable but under favorable conditions is from 6 to 8 weeks.

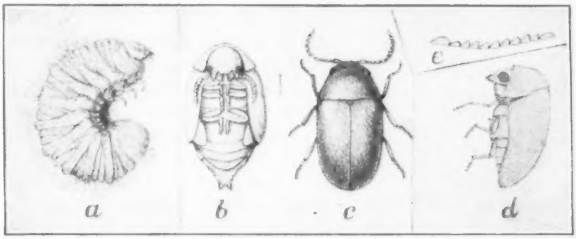

FIGURE 51.—The cigarette beetle: *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. The beetle is usually about one-tenth of an inch long.

DRUG-STORE WEEVIL

The drug-store weevil (*Stegobium paniceum* (L.)) is very similar in appearance to the cigarette beetle, to which it is closely allied, but differs from it by being more elongate in proportion and in having the wing covers distinctly striated. It is about one-tenth of an inch long, cylindrical, and uniform light brown, its body covered with a fine silky pubescence (fig. 52). The larva, or grub, is very much less

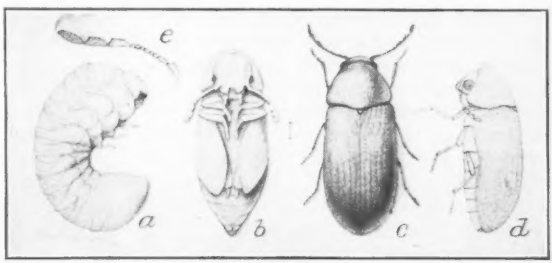

FIGURE 52.—The drug-store weevil is about one-tenth of an inch long. It never attacks grain unless it is stored for long periods unmolested: *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle.

hairy than that of the cigarette or tobacco beetle. It is known as the drug-store weevil from its habits of feeding on almost all drugs found in pharmacies. It is a very general feeder, attacking a great variety of stored foods, seeds, and other materials, and has been said to "eat anything except cast iron." It is frequently found in storehouses and granaries in all parts of the world.

The eggs of this beetle are laid in almost any dry organic substance. The small white grubs emerging from the eggs tunnel through these substances and when full grown pupate in small cocoons. The entire life cycle may be passed in less than 2 months.

CATORAMA BEETLE

Another beetle closely related to the drug-store weevil and the cigarette beetle and which has similar habits is the catorama beetle (*Catorama* sp.), which is shown in figure 53. It is shiny black and is about one-eighth of an inch long. It is only an occasional pest of stored grain and does not cause serious damage.

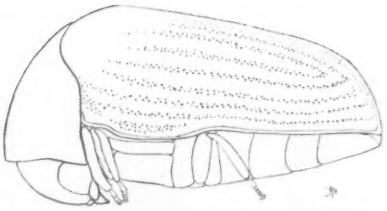

FIGURE 53.—The catorama beetle. This beetle is about one-eighth of an inch long.

BOOKLICE OR PSOCIDS

Grain and grain products are sometimes found to be swarming with minute insects that are scarcely larger than a pinhead. Flour and grain samples appear to be particularly attractive to them. They are known as psocids, or booklice, owing to their resemblance to lice and their occasional presence in books. One of the most abundant of these psocids is the common booklouse (*Troctes divinatorius* (Müll.)) (fig. 54). It is a tiny, pale-grayish or yellowish-white, wingless, soft-bodied louselike insect with a fairly large head, poorly developed eyes, and long, slender antennae. It is about one twenty-fifth of an inch in length. It feeds on a great variety of organic matter, both of plant and animal origin, but is troublesome through its presence rather than for the actual damage it causes.

The females reproduce without mating; in fact, no males are known to exist. As many as 100 eggs may be laid by a single female, and in summer the developmental period from egg to the mature insect is about 3 weeks. The newly hatched young resemble the mature insects in form and general appearance but are smaller and of a lighter color. This insect is widely distributed in North America and Europe.

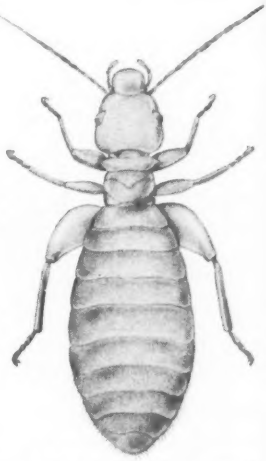

FIGURE 54.—Booklouse or psocid.

A closely related species, *Trogium pulsatorium* (L.), known as the death watch, is similar in appearance and habits and is found under the same circumstances. It may be distinguished from the common booklouse by the fact that it is slightly larger, has a pair of diminutive wing covers, and has well-developed eyes. It also is widely distributed over North America and Europe but is not quite so common or abundant as the preceding species.

SILVERFISH

A rather common insect in mills, warehouses, and dwellings is a glistening, silver or pearly-gray insect known as a silverfish or slicker (*Lepisma saccharina* L.). As shown in figure 55, the pos-

session of three long taillike appendages gives it a characteristic appearance easily recognized. It is cosmopolitan in distribution and feeds on starchy foods of all kinds. It is found particularly in dark, moist, warm situations.

A closely related species, *Thermobia domestica* Pack., known as the firebrat, is found in similar situations and closely resembles the silverfish in appearance and habits. It may be readily differentiated from this species by the fact that instead of having a uniform silvery color, it is pearly white, heavily mottled along the back, with dusky scales that give it a banded appearance. It is probably cosmopolitan in distribution and in some places is more abundant than the silverfish. Development from egg to adult is completed in from 11 to 12 weeks.

FIGURE 55.—Adult silverfish, about two and one-fourth times natural size.

COCKROACHES

Cockroaches are of frequent occurrence in establishments handling cereal products, and everybody is familiar with their appearance. They are particularly abundant in the basements of buildings in dark, moist situations, and when lights are suddenly turned on, it is not uncommon to see the floors of basements almost black with them. The oriental cockroach (*Blatta orientalis* L.) (fig. 56) is probably the commonest species found in flour mills and food establishments in North America. It is a large roach, dark brown or black, measuring when full-grown about an inch in length. The females are unique in that they have no wings—merely short wing pads. The males have fully developed wings.

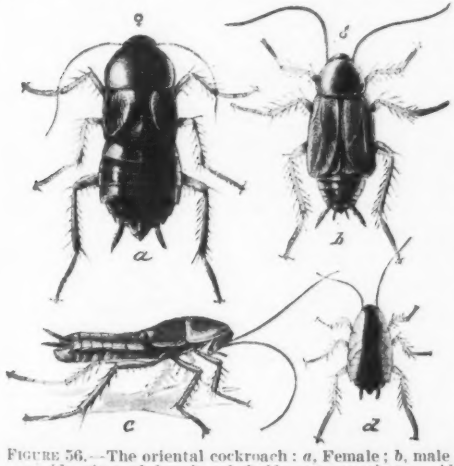

FIGURE 56.—The oriental cockroach: *a*, Female; *b*, male; *c*, side view of female; *d*, half-grown specimen. All natural size.

A closely related species, *Periplaneta americana* (L.), known as the American cockroach, is also quite abundant and in many flour mills in the Southwestern and Midwestern States is the predominant form. It is even larger than the oriental cockroach and frequently is 1½ inches

in length. It is bright sienna brown except for the pronotum, which is brownish yellow and encloses the characteristic, irregular-shaped, reddish-brown double spot in the center. It is shown in figure 57.

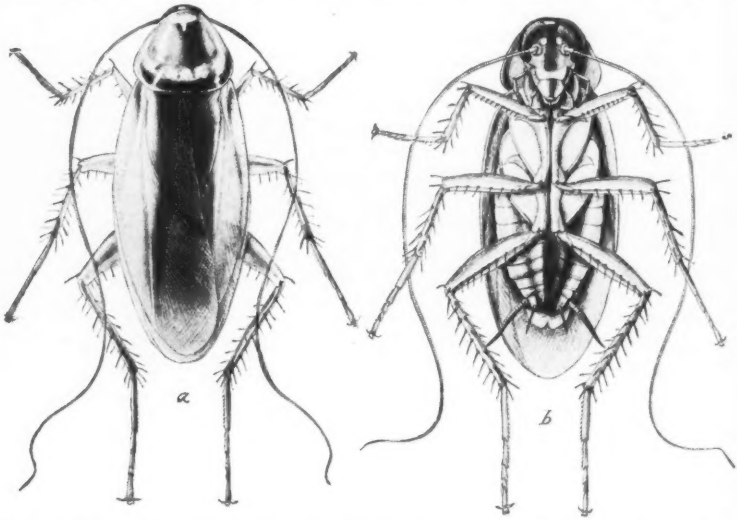

FIGURE 57.—The American cockroach: *a*, View from above; *b*, from beneath. Enlarged one-third.

FLOUR OR GRAIN MITES

The flour or grain mites are pale, grayish-white, smooth, soft-bodied creatures microscopic in size, and provided with numerous long hairs on the legs and back, as shown in figure 58. Mites are not true insects, as the adults have eight legs and the body is indistinctly divided into two parts. They have no wings. The flour or grain mites are much smaller than the booklice, being usually less than one-fiftieth of an inch in length. They are often found in stored grain and occasionally increase with such rapidity that the grain seems to be fairly alive with them. During heavy infestations their cast skins and dead bodies accumulate in fluffy light-brown masses beneath the sacks of grain. If these accumulations are on a warehouse floor, they roll up into piles, which are blown about with each gust of wind. No other group of pests in grain will produce these masses. When present in large numbers, they promote sweating, impart a disagreeable odor to the grain, and may cause damage by their feeding. Fortunately the mites that attack grain are themselves preyed upon by predacious mites, which usually become abundant enough to kill the grain mites in a comparatively short time. If they do not, the screening and fanning of grain will usually reduce mite infestations to a point where no injury takes place.

The most injurious species of mite found in flour, grain, and cereal products in North America is *Tyroglyphus farinae* (Deg.), which is popularly known as the flour mite, common forage mite, or grain

mite. It multiplies with great rapidily under favorable conditions and may complete its life cycle from egg to mature mite in a little over 2 weeks.

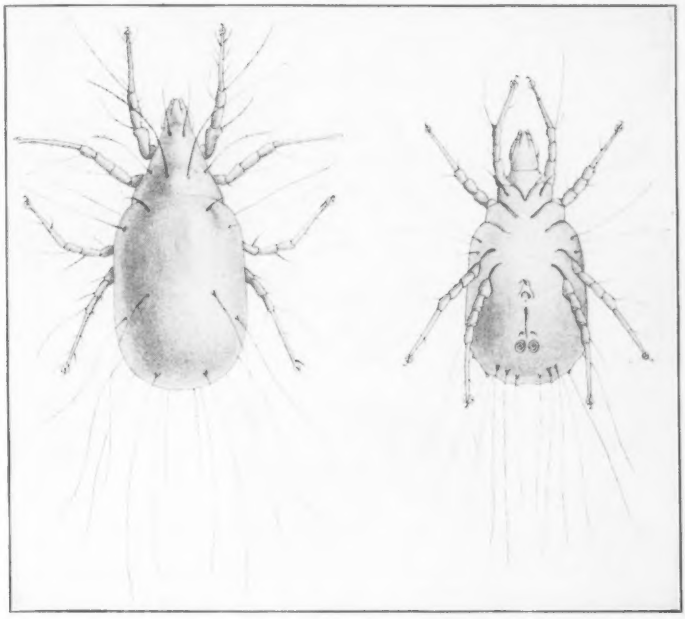

FIGURE 58.—Grain mites.

Another very common species, *T. longior* Gerv., also known as the flour mite, but sometimes as the cheese mite, is similar in appearance and habits to the preceding species.

PARASITES OF GRAIN PESTS

Grain in bulk is sometimes seen swarming with small wasplike creatures of the size and appearance shown in figure 59. Similar insects may also be seen on the windows of flour mills and other establishments where cereal products are handled. These insects are not harmful but beneficial in that they attack and destroy the insects that infect grain and grain products.

The small parasite shown resting on the kernel of wheat in figure 59 is the adult of *Aplastomorpha calandrae* (How.), the most important parasite of the rice and granary weevils. The female wasp

FIGURE 59.—*Aplastomorpha calandrae*, a hymenopterous parasite of grain pests resting upon a kernel of wheat.

is able to detect the presence of the grain weevil grub hidden from sight within the grain and paralyzes it with a few thrusts of the ovipositor. A single egg is then deposited on the exterior of the grub or in close proximity to it. The egg hatches, and the parasite grub feeds on the paralyzed weevil grub, thus destroying it. The developmental period from egg to adult is about 2 weeks. A single female parasitic wasp has been observed to lay as many as 283 eggs, but the help usually comes too late to prevent damage to the crop.

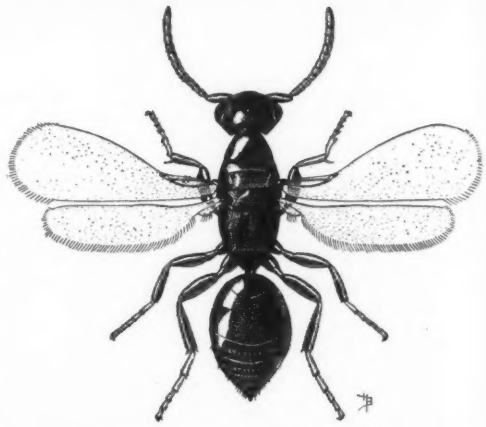

FIGURE 60.—*Cephalonomia tarsalis*, adult. × 21.

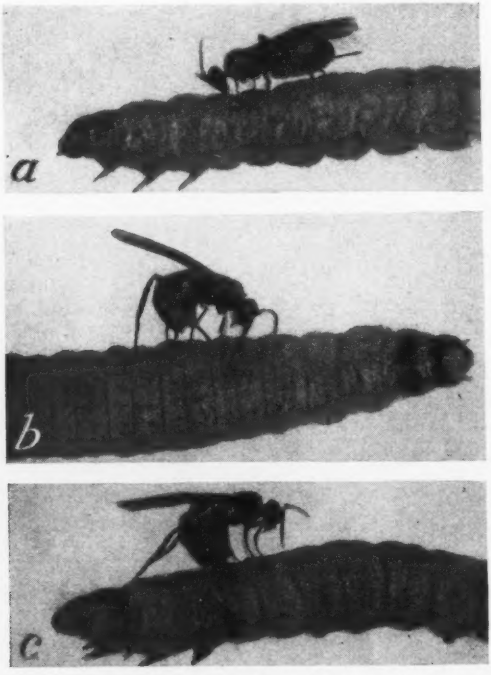

FIGURE 61.—Female of *Microbracon hebetor* in three poses: *a*, Feeding on the body fluids of a larva of the Mediterranean flour moth and showing the short, straight ovipositor protruding behind; *b*, the parasite in the position assumed in puncturing the body of the larva preparatory to laying an egg; *c*, the parasite with the ovipositor well inserted in the larva and about to lay the egg.

Another fairly common parasite of the grain beetles is shown in figure 60. This parasite, *Cephalonomia tarsalis* (Ashm.), has habits quite similar to those of the preceding species.

The adult of *Microbracon hebetor* (Say) attacking larvae of one of the meal or flour moths is illustrated in figure 61. This little wasp is one of the most important parasites of these moths. It first paralyzes the flour moth caterpillar by stinging it several times.

Then it places several eggs on the paralyzed caterpillar. These eggs hatch into small, white, footless, grublike larvae that suck the body

FIGURE 62.—*Idechthis canescens.* × 8.

juices of the caterpillar. Under favorable circumstances this parasite completes its development from egg to adult wasp again in less than 2 weeks.

Another beneficial wasp that is of even greater importance as a parasite of the flour and meal moths is *Idechthis canescens* (Grav.). This slender wasp (fig. 62) has a reddish-brown abdomen, with head and thorax black and legs a reddish brown to yellow.

The habits of this parasite are somewhat different from those of the preceding species. The adult wasp deposits its eggs inside the body of the flour moth caterpillar and the entire development of the parasitic larva, until just before pupation, takes place within the host. The host caterpillar is not paralyzed and continues feeding until the parasitic larva has become nearly full grown. The developmental period from egg to adult requires between 3 and 4 weeks.

FIGURE 63.—Larva of a kind of fly that preys upon grain beetles and mites. This white threadlike worm sometimes attains a length of about three-fourths of an inch.

Grain dealers and millers not infrequently find a small, threadlike, white worm (fig. 63), about three-fourths of an inch long, in accumulations of flour or grain dust. This is the larve of a small black fly, *Scenopinus fenestralis* (L.) (fig. 64), known as the windowpane fly from its frequenting the windows of mills and similar establishments. This white worm does not injure grain or cereal products but is a predator on other insects found in mills and warehouses. *S. glabrifrons* Meig. is a closely allied species, also known as a windowpane fly.

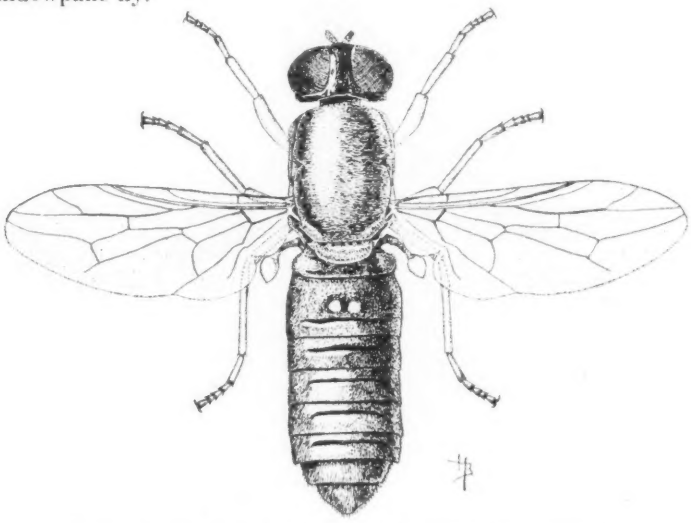

FIGURE 64.—Adult of the windowpane fly (*Scenopinus fenestralis*).

HOW GRAIN BECOMES INFESTED

Grain may become infested in a number of ways. It is never possible satisfactorily to settle litigation over responsibility for insect damage to grain without a thorough knowledge of the history of the particular grain shipment involved.

Several of the worst insect pests of grain, notably the Angoumois grain moth and the rice or black weevil, fly to the grainfields from nearby cribs and begin their attack upon the maturing grain. In the case of wheat and similar small grains the eggs of the insect are laid directly upon the heads of grain. In the case of corn the insects can infest only those kernels that are exposed because of poorly developed or damaged shuck covering. In cornfields, especially in the South, where insect infestation occurring in the field is most severe, there are a sufficiently large number of exposed kernels to bring about slight, though widespread, infestation.

It is probably true that in well-grown crops of corn the percentage of kernels infested before the crop is ready for harvest is very small, and throughout the Middle and Northern States is a negligible factor. In the Gulf Coast States, especially in upland fields, the infes-

tation often is very severe. In the case of wheat, grown particularly along the Ohio River, in southern New Jersey, in Pennsylvania, Maryland, Delaware, Virginia, and southward, the field infestation may be much more general than is now believed. Newly threshed wheat from Maryland arriving in September on the Baltimore market showed infestation ranging up to 6 percent. While these infestations occurring in the grain before it is harvested are usually unavoidable, they are of great importance as "leaven" which in storage may result in a general infestation of an entire crop, in heating, and in much damage.

After grain has been harvested it is often stored in bins, storehouses, or barns that have held, or still hold, infested grain and which have not been thoroughly cleaned. Wooden bins and wooden partitions in grain storehouses and in the holds of grain-carrying ships becomes the nesting places for an incredibly large number of grain pests. Certain of these can and do bore into the softer portions of the partitions and timbers that are used over and over again as dunnage, and the excavations they make serve as hiding places, not only for themselves but for all other species associated with them. Unless such bins and partitions are thoroughly disinfected by fumigants, these hidden insects cannot be killed. The mere spraying of contact insecticides upon the walls will not reach them. If uninfested grain is placed in such bins, it naturally will become infested by the insects coming from the bin walls.

Likewise, uninfested grain should not be placed for shipment in sacks previously used for grain storage, for, as shown in figure 24, these old sacks often harbor insects unless they have been treated by heat or fumigation. Certain extensive and costly infestations have been traced directly to the use of second-hand untreated grain sacks.

Grain stored in the open or in poorly constructed cribs or bins may become infested by insects flying in from outside.

HOW TO PREVENT PRIMARY INFESTATION

Infestation of grain in the field cannot be entirely prevented, but by proper precautions it can be reduced to a minimum. The first generation of insects in the maturing grain is usually small, and if the grain is cut as soon as ripe, threshed as soon as dry, and then placed in storage in clean, deep bins the damage from this source will be very slight. It is when the grain is left in the field long after it is ripe that serious infestation results, for the insects increase in one or two generations to enormous numbers. In the case of corn in the field, only those ears that are damaged or through poor shuck development have kernels exposed are subject to the attack of grain insects. Farmers should therefore grow a variety of corn that develops a long tight shuck.

Newly harvested small grains should not be stored unthreshed for any length of time, as in this condition they are very susceptible to infestation. If promptly threshed and stored in deep bins, only a thin layer on top of the bin is likely to become infested. Corn may be stored in the shuck if the husk is long and tight and fully covers the tip, but all ears with loose, broken, short, or damaged husks should be shucked and stored separately.

Clean grain should never be stored in old bins, granaries, or storehouses until they have been thoroughly cleaned and freed from the accumulations of waste grain and other materials harboring grain insects. Timbers in bins, granaries, or holds of ships that have become infested with grain insects should be destroyed or treated before being used again. Steel or concrete bins are highly desirable owing to the ease with which they are cleaned.

Bags of all kinds that have previously held grain should not be allowed in granaries or warehouses or be refilled until they have been sterilized by heat or otherwise freed from insects. The use of tight cribs will keep the grain free from infestation by insects that might fly in from the outside.

THE TREATMENT OF INFESTED GRAINS

Insects infesting stored grain can be destroyed by the use of heat, or by fumigation with poisonous gases. These remedial measures are mentioned only briefly in this bulletin.

HEAT

A temperature of 120° to 130° F., maintained for a short time, will kill all stages of grain-infesting insects, without injuring the germinating quality of the grain. Owing to the difficulty of subjecting the grain to such a temperature this method of control is used chiefly by millers and large grain dealers who are equipped with commercial driers suitable for the purpose.

FUMIGATION

Carbon disulphide, hydrocyanic acid, chloropicrin, and mixtures of carbon tetrachloride with carbon disulphide or ethylene dichloride are the fumigants in most common use today for treating infested grain.

For treating bulk grain on the farm, carbon disulphide is the most effective and economical fumigant to use. It is a colorless liquid which evaporates on exposure to air, forming a vapor that is heavier than air. If applied at the top of a gastight bin of grain, the gas will penetrate down through the grain, killing the insects without injury to sound grain.

Carbon disulphide has the great disadvantage that its vapor is highly inflammable and, when mixed with certain proportions of air, will explode if ignited. Notwithstanding this fire hazard, which must always be taken into consideration, carbon disulphide is in general use on farms for the protection of grain in cribs. For further information on fumigation with carbon disulphide see Farmers' Bulletins 799, Carbon Disulphide as an Insecticide, and 1483, Control of Insect Pests in Stored Grain.

The other fumigants mentioned are adapted principally for use in treating grain in large elevators. A crude granular calcium cyanide containing from 23 to 29 percent of available hydrocyanic acid is applied by being fed into the grain stream at the rate of 10 pounds per 1,000 bushels as the large elevator bins are filled. On exposure to air the calcium cyanide unites with the atmospheric moisture to form hydrocyanic acid. Since hydrocyanic acid gas is

deadly to human life, this fumigant should be handled only by an expert fumigator.

Chloropicrin is a noninflammable tear gas, highly toxic as a fumigant for grain insects. A dosage of 2 pounds per 1,000 bushels of grain, with an extra pound for the first and last 1,000 bushels, is the standard dosage used in large grain elevators. It is applied by dripping it into the grain stream as the bins are filled. The operator handling the chloropicrin should wear a gas mask for protection against the fumes.

The mixtures of carbon tetrachloride with carbon disulphide or ethylene dichloride are usually applied as the grain is being run into the elevator bins by being sprayed, poured, or dripped into the grain stream. A dosage of from 1½ to 2 gallons per 1,000 bushels of grain is used.

Further information regarding the control of grain pests will be found in Farmers' Bulletin 1483.

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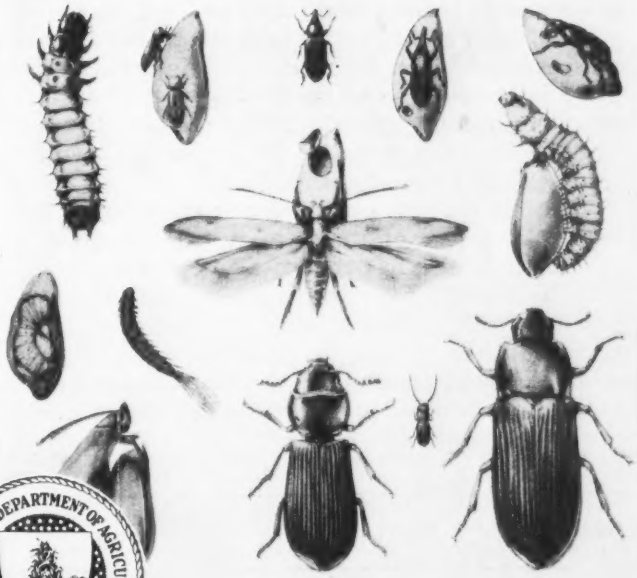
FARMERS' BULLETIN No. 1260
Rev. May 1940

STORED-GRAIN PESTS



UM

MOST of the damage done by insects to grain in storage and shipments is brought about by four species. These are the granary weevil, the rice or black weevil, the lesser grain borer or Australian wheat weevil, and the Angoumois grain moth. Other species or groups of species described in this bulletin can cause great damage to grain if storage conditions are unusually favorable for their increase. Yet if grain in the unbroken kernel remains unaffected by the four insects mentioned, it is not likely, in commercial storage or shipments, to be sufficiently affected by other insects to cause appreciable loss.

The secondary pests discussed herein are for the most part surface feeders in both adult and larval stages. Some may eat their way into kernels of grain and lie hidden there; most of them are found feeding upon grain dust or broken surfaces of kernels exposed either by mechanical injuries to the grain in handling or by the feeding of the four primary grain pests with which they are usually associated. They can therefore be largely removed by grain-cleaning operations.

With the exception of the lesser grain borer, the larvae, or grubs, of the primary pests mentioned are not ordinarily capable of a free existence outside the kernel. They live entirely within the kernel, where they feed unseen and usually unsuspected. They cannot be removed by ordinary cleaning machinery and must be controlled by other means. Methods of preventing infestation of grain are discussed briefly.

Washington, D. C.

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STORED-GRAIN PESTS

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POPULAR CLASSIFICATION OF GRAIN PESTS

SINCE THE ESTABLISHMENT of the Federal standards for grain under the provisions of the Grain Standards Act, Federal grain supervisors and federally licensed grain inspectors have been required to identify the various species of "live weevils and other insects injurious to stored grain" which may be present in the grain. Uniform names for grain insects should be used. Such uniform terminology will indicate definitely to all interested persons, including shipper, purchaser, and elevator operator, the exact nature of the insect found. Of the four major pests, the granary weevil, the rice or black weevil, and the lesser grain borer may well be called grain weevils. The fourth of the major pests, the Angoumois grain moth, so destructive to wheat and corn, may be called grain moth. Other insects likely to be found in any lot of grain may be called simply beetles, moths, and mealworms, for their presence

usually does not indicate a condition likely to affect the trade, provided that after the grain has reached the elevator it is screened and fanned to remove these insects.

In this bulletin are discussed grain weevils, grain borers, grain moths, flour moths, grain and flour beetles, mealworms, dermestid beetles, spider beetles, miscellaneous beetles, booklice, or psocids, silver-fish, cockroaches, flour or grain mites, and parasites of grain pests.

GRAIN WEEVILS

Of the four true weevils that attack grain in the United States, only two are of primary importance—the granary weevil and the rice or black weevil. The broad-nosed grain weevil and the coffee-bean weevil are of minor importance, except locally. These four weevils have elongated beaks or snouts, as the illustrations show, though the beak of the coffee-bean weevil is greatly reduced.

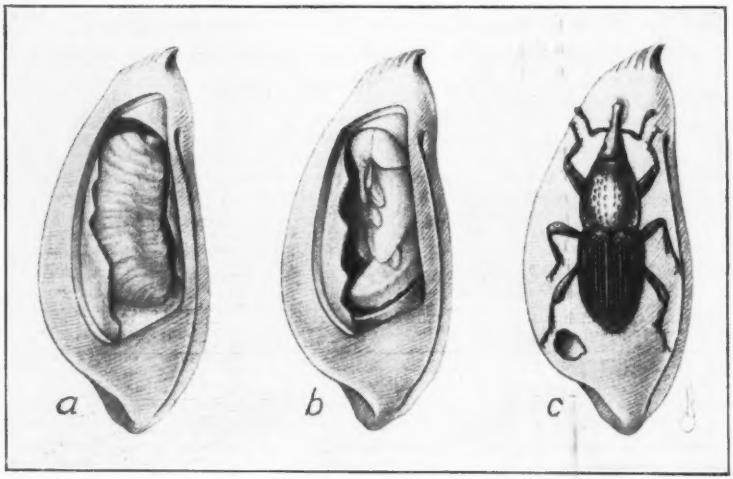

FIGURE 1.—Life stages of the granary weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult. Note hole in kernel made by the adult in order to leave the seed and hole that it is eating into the kernel for the purpose of laying eggs. The adult is never more than three-sixteenths of an inch long.

GRANARY WEEVIL

The granary weevil (*Sitophilus granarius* (L.)) (fig. 1) is a small, moderately polished, chestnut-brown or blackish beetle with head prolonged into a long slender snout, at the end of which are a pair of stout mandibles or jaws. It is not more than three-sixteenths of an inch long and often is smaller. It has no wings under its wing covers, and the thorax is well marked with longitudinal punctures, two characteristics that distinguish it from the closely related rice weevil, with which it is often found associated. The well-grown footless, whitish grub or larva and the pupa are shown in figure 1, *a* and *b*. The granary weevil is one of the oldest known insect pests,

is a universal feeder upon grains, and is cosmopolitan, having been carried by commerce to all parts of the world. It prefers a temperate climate and is more frequently found in the Northern States than in the South.

Both adults and larvae feed voraciously on a great variety of grains. The adult weevils live, on an average, from 7 to 8 months, the females laying from 50 to 250 eggs each during this period. Before laying her eggs the female bores a small hole in the grain berry with her mandibles. When this has been made she turns about and lays in it an egg, which she then covers with a gelatinous fluid that seals the hole. The small, white, fleshy, and legless grubs that hatch from the eggs burrow about inside the kernels. When fully grown, these transform to the pupal stage and then into the adult-weevil form.

In warm weather the granary weevil requires about 4 weeks to complete its development from the egg to the adult weevil. The developmental period is greatly prolonged by cold weather.

RICE OR BLACK WEEVIL

The rice or black weevil (*Sitophilus oryzae* (L.)) is a small snout-beetle which varies considerably in size but rarely measures more than one-eighth of an inch in length (fig. 2). It varies in color from reddish brown to nearly black and is usually marked on the back with four light reddish or yellowish spots. It closely resembles the granary weevil in form, but it has well-developed wings beneath its wing covers, differs in color and markings, and has the thorax densely pitted with round, instead of longitudinal punctures. Figure 2 gives a good impression of the appearance of the rice weevil and its earlier stages.

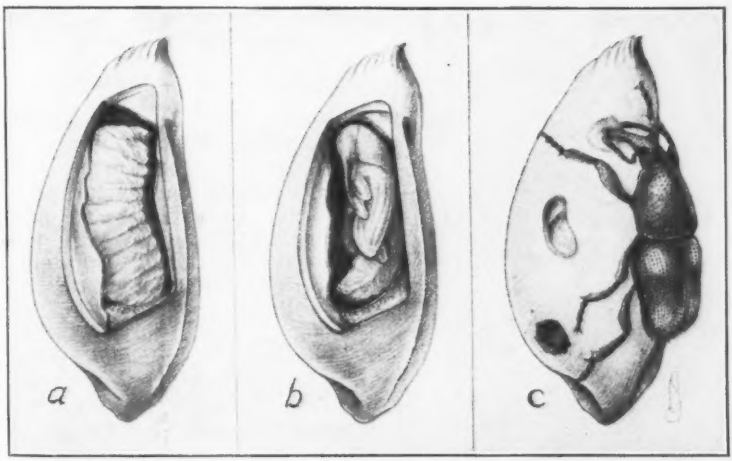

FIGURE 2.—Life stages of the rice or black weevil in wheat: *a*, Well-grown larva; *b*, pupa; *c*, adult feeding upon kernel. Note in *c* the hole in lower portion of kernel made by the adult on leaving the seed and at two points higher up shallow holes made by the adult in feeding upon the seed after emergence. The adult rarely measures more than one-eighth of an inch in length.

This weevil has been known from early times. It is found in all parts of the world where grain is used and is one of the very worst pests in stored grain. It is particularly abundant in warm countries, where it breeds continuously and rapidly destroys all unprotected grain. Throughout the South it causes tremendous losses to corn (fig. 3), reducing the kernels to dry powder and hulls, and is the commonest of the serious pests of commercial grain shipments.

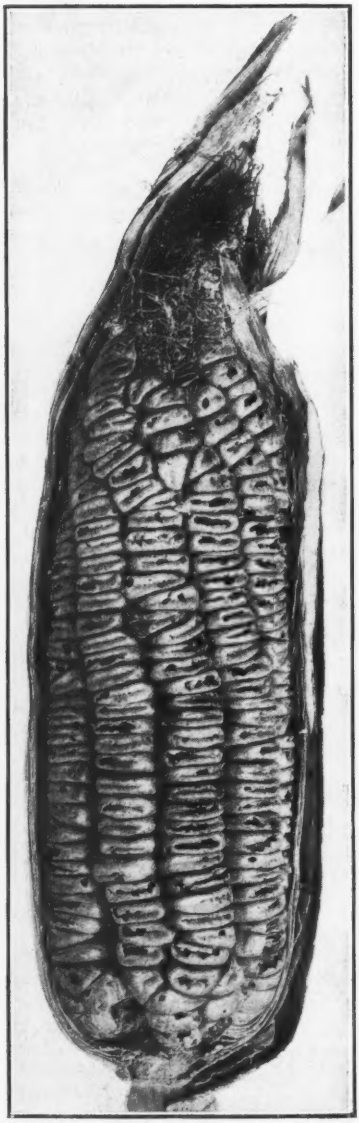

FIGURE 3.—An ear of corn badly damaged by rice or black weevils. This ear has been hit against a table to jar loose the powdery substance, sometimes called the farinaceous material, and so reveals the great damage done by the weevils.

The adult weevil lives, on an average, 4 or 5 months, each female laying between 300 and 400 eggs during this period. The early stages are almost identical in habit and appearance with those of the granary weevil and need not be further described. The rice weevil is a strong flier. The adults fly from granaries to the fields of grain and there start the infestation that often proves so disastrous after the grain has been harvested. During summer weather the egg, larval, and pupal stages may be passed in as few as 26 days. This period, of course, is greatly prolonged during cool or cold weather. For a further discussion of this pest see Farmers' Bulletin 1811, Control of Insects Attacking Grain in Farm Storage.

BROAD-NOSED GRAIN WEEVIL

The broad-nosed grain weevil (*Caulophilus latinasus* (Say)) is a small dark-brown snout beetle slightly less than one-eighth of an inch long. In form and color it resembles the granary weevil somewhat but differs from it and from other grain-infesting weevils by having a short, broad snout (fig. 4).

This weevil is occasionally found in Georgia and South Carolina and is widespread in Florida, where it is a serious pest of stored grains, but it is not found in grains grown in the North. It is unable to breed in dry, hard, uninjured grain, but attacks soft or damaged grain, or grain that has been attacked by other grain insects. It is

a strong flier, and, like the rice weevil, flies to the cornfields and infests the grain before it becomes fully hardened.

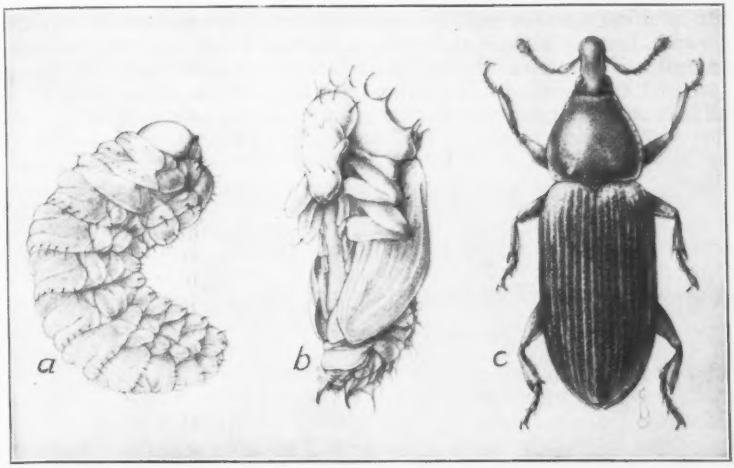

FIGURE 4.—The broad-nosed grain weevil: *a*, Full-grown larva; *b*, pupa; *c*, adult weevil. The adult weevil is slightly less than one-eighth of an inch long.

The adult weevils normally live for about 5 months, and during this time the females lay between 200 and 300 small white eggs, usually in broken portions of the grain. The eggs hatch in a few days, and the small, white, legless grubs feed on the softer portions of the grain until fully grown. They then change to a white pupal form, which in a few days transforms to the adult beetle and cuts its way out of the grain. In summer the period from egg to adult is about 1 month.

COFFEE-BEAN WEEVIL

The coffee-bean weevil (*Araecerus fasciculatus* (Deg.)) is a very active, robust dark-brown beetle from two-sixteenths to three-sixteenths of an inch long, clothed with a mottled light- and dark-brown pubescence. It may be easily recognized from figure 5.

This weevil is found in many countries and is extremely abundant in the Southern States, where it breeds in dried fruit, coffee berries, cornstalks, corn, and the seed and seed pods of an almost endless variety of plants. It is a strong flier and is frequently to be seen in the cornfields of

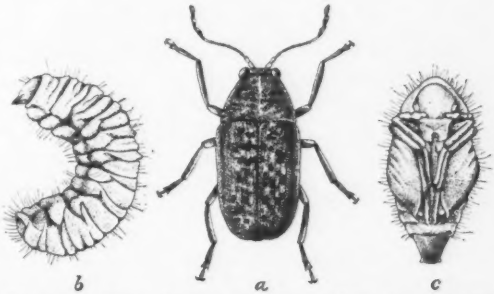

FIGURE 5.—The coffee-bean weevil: *a*, Adult; *b*, well-grown larva; *c*, pupa. The adult is about three-sixteenths of an inch long.

the South on the exposed and damaged ears. It lays its eggs in the soft kernels of corn, and breeding continues after the corn has been harvested and placed in storage. It does not cause much damage to corn in storage, as the corn becomes too hard to be attractive. It may, however, be very abundant locally in corn in Florida during the first 3 months of storage and has been reported as completely destroying a sack of kafir seeds in Honolulu. Taking the country at large, the coffee-bean weevil is a very minor grain pest.

GRAIN BORERS

Three species of grain borers are now established in the United States. The lesser grain borer is now widespread in the grain centers of this country and is a serious pest of stored grain. The larger grain borer and the bamboo borer are confined to the Southern States and are not of commercial importance.

LESSER GRAIN BORER

The lesser grain borer (*Rhizopertha dominica* (F.)) is one of the smallest beetles injurious to grain in this country. It is known to many grain dealers more popularly as the Australian wheat weevil

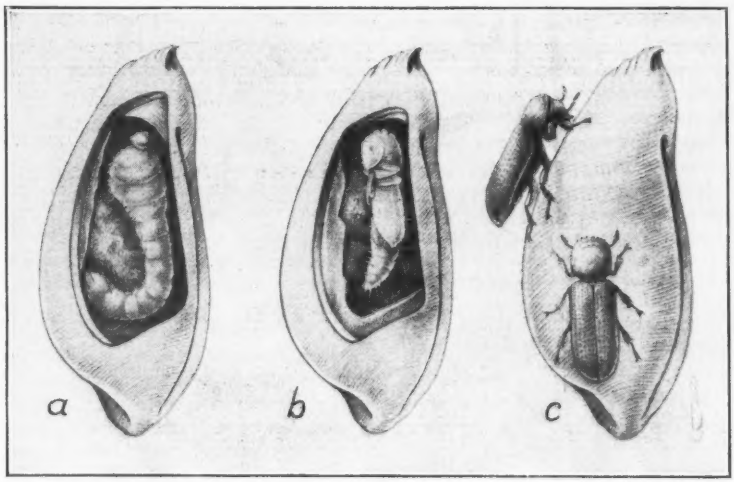

FIGURE 6.—The lesser grain borer in and on wheat kernels: *a*, The well-grown larva; *b*, the pupa; *c*, two adult weevils. Adult borer is about one-eighth of an inch long.

because of the large supplies of wheat infested by it that reached this country from Australia during the World War. It is widespread in the Gulf States, and grain samples infested with this beetle are to be found in all large grain centers. It is readily distinguished from other grain pests by its slender cylindrical form and small size. It is polished dark brown or black, with a somewhat roughened

surface, about one-eighth of an inch long and one thirty-second of an inch wide. The larval, pupal, and adult stages are illustrated in figure 6. It belongs to a family (Bostrichidae) of beetles that have the head turned down under the thorax and are armed with powerful jaws with which they can cut directly into wood. Originally native to the Tropics, the lesser grain borer has spread through commerce to all parts of the world.

Both beetles and larvae cause serious damage in warm climates, attacking a great variety of grains. The destruction of which they are capable is shown by the wheat kernels of figure 7, which are literally riddled by the boring adults and their young. The damaged kernels are always surrounded by powder from the chewed-up grain. The females lay from 300 to 500 eggs each, dropping them singly or in clusters in the loose grain. The eggs hatch in a few

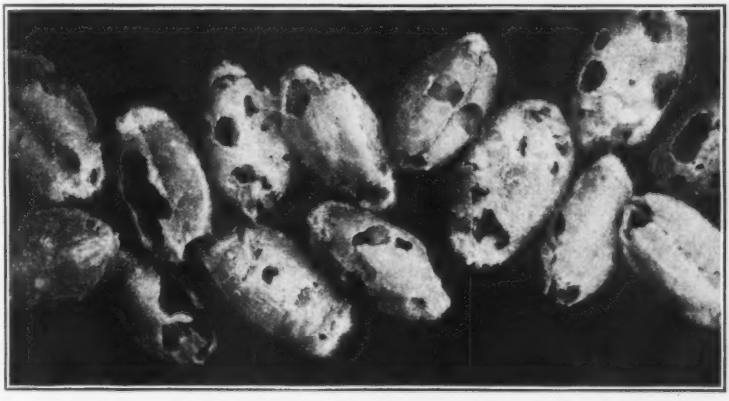

FIGURE 7.—Kernels of wheat thoroughly riddled and devoured by the boring and feeding of the lesser grain borer and its larva.

days, and the small whitish grubs crawl actively about the grain, feeding on the flour produced by the boring of the beetles, or boring directly into grains that have been slightly damaged. They complete their growth within the grain, transform to white pupae, and in time change to adult beetles which cut their way out of the grain. The period from egg to adult in summer is said to be about a month.

LARGER GRAIN BORER

The larger grain borer (*Stephanopachys truncatus* (Horn)), is a small, dark-brown, elongate-cylindrical beetle about one-sixth of an inch long. As may be seen in Figure 8, it is very similar in appearance to the lesser grain borer, but it may be distinguished by its larger size and comparatively smooth, polished surface.

This beetle is a tropical insect not as yet widely distributed in this country. It is occasionally found infesting corn (fig. 9) in the South. It has been reported from Texas, California, and the Dis-

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trict of Columbia. Like the lesser grain borer, it belongs to a family of beetles (Bostrichidae) that are mainly destructive to timber

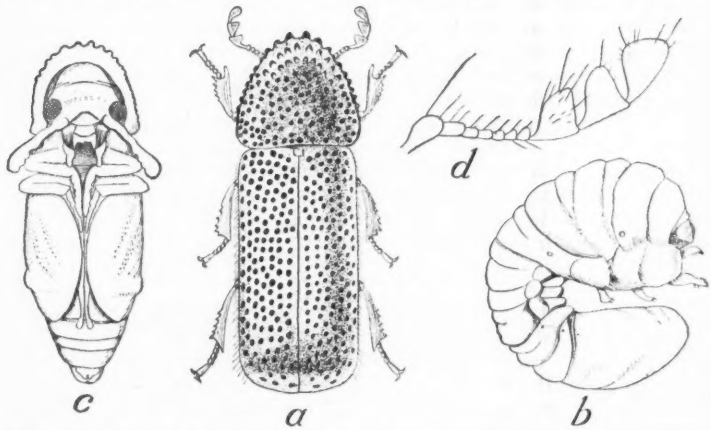

FIGURE 8.—Adult and immature stages of the larger grain borer: *a*, Adult insect; *b*, larva; *c*, pupa; *d*, antenna of adult. The adult beetle is about one-sixth of an inch long; the antenna in *d* is highly magnified.

and has habits similar to those of that beetle. It also has probably acquired its grain-feeding habits rather recently.

FIGURE 9.—Kernel of corn showing the work of the adult of the larger grain borer.

One other member of the family Bostrichidae, *Dinoderus minutus* (F.), the bamboo borer, occasionally infests stored grain in the United States. It has been recorded from Louisiana and Florida. In general appearance it resembles the larger grain borer.

GRAIN MOTHS

The term "grain moth" includes only those moths capable of destroying sound, unbroken grain kernels. They are not so abundant as the flour moths, which are principally pests in broken, damaged kernels or milled products.

ANGOUMOIS GRAIN MOTH

The Angoumois grain moth (*Sitotroga cerealella* (Oliv.)) is a small bluff or yellowish-brown moth with a wing expanse of about one-half inch. This is the moth most commonly found in infested grain in this country and is not likely to be confused with any other. It attacks all cereal grains, is found in all parts of the world, and is particularly injurious in the South, where it attacks grain both in the field and in storage. In the North it survives the winter, for the most part as larvae in kernels of grain in storage and in scattered wheat in litter, straw piles, and baled straw. The emerging moths fly to the wheatfields in May and deposit eggs upon the developing grain.

Under normal conditions each female lays an average of about 40 eggs, although under favorable conditions individual moths have been known to lay as many of 389 eggs. The eggs, which are white

when first laid, soon change to a reddish color. They are laid on wheat heads, on the exposed tips of ears of corn in the field, or on grain in storage. Upon hatching, the young larva crawls to a kernel of grain and often spins a small entrance cocoon to assist it in boring into the hard kernel. After entering the grain, it feeds on either the endosperm or the germ until fully grown, when it eats out a channel to the outside of the seed and prepares an exit hole through the seed coat by cutting the shell for one-half or three-fourths of the circumference of a circle, making a weakly fastened flap. A silken cocoon is spun, and the larva changes to a reddish-brown pupa. Later a moth pushes its way through the partly cut flap.

The period from egg to adult may be completed in 5 weeks, although development is usually slower than this. In years favorable to this insect great damage is caused to harvested wheat unless it is promptly threshed. As the delicate moths are unable to penetrate beneath the surface of stored grain, infestation is restricted to the surface kernels. Figure 10 shows an ear of corn with the external evidence of a heavy attack by the Angoumois grain moth. Figure 11 shows the successive stages in the development of this insect in a kernel of wheat from the time the egg is laid until the adult appears.

For a further discussion of this insect, see Technical Bulletin 351, Life History of the Angoumois Grain Moth

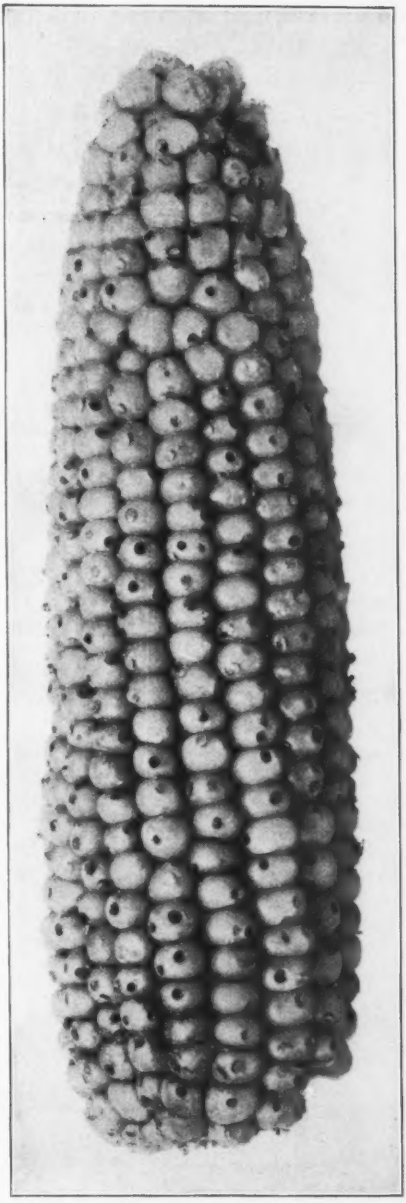

FIGURE 10.—Ear of popcorn showing heavy infestation by the Angoumois grain moth. Note that certain of the kernels have three emergence holes, and that many have served as food for two larvae.

in Maryland, and Farmers' Bulletin 1156, The Angoumois Grain Moth.

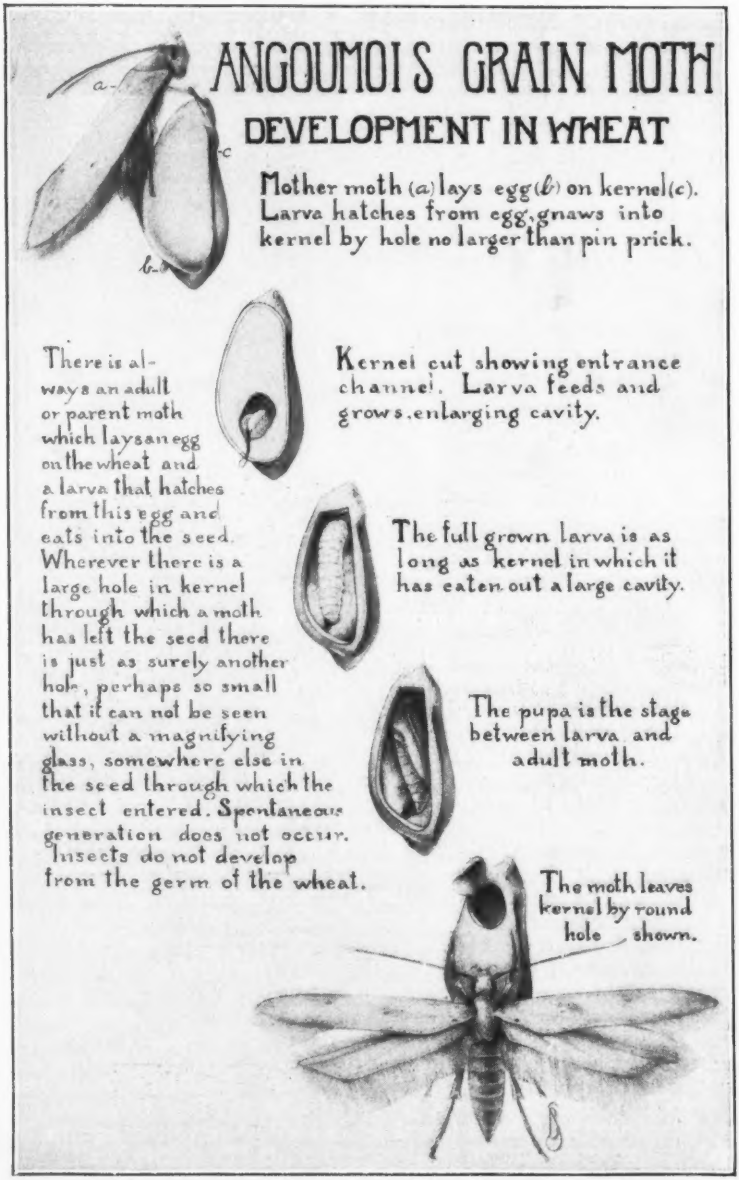
ANGOUMOIS GRAIN MOTH
DEVELOPMENT IN WHEAT
Mother moth (a) lays egg (b) on kernel (c). Larva hatches from egg, gnaws into kernel by hole no larger than pin prick.
a
b
c
There is always an adult or parent moth which lays an egg on the wheat and a larva that hatches from this egg and eats into the seed. Wherever there is a large hole in kernel through which a moth has left the seed there is just as surely another hole, perhaps so small that it can not be seen without a magnifying glass, somewhere else in the seed through which the insect entered. Spontaneous generation does not occur. Insects do not develop from the germ of the wheat.
Kernel cut showing entrance channel. Larva feeds and grows, enlarging cavity.
The full grown larva is as long as kernel in which it has eaten out a large cavity.
The pupa is the stage between larva and adult moth.
The moth leaves kernel by round hole shown.

FIGURE 11.—Life cycle of the Angoumois grain moth on wheat.

EUROPEAN GRAIN MOTH

The European grain moth (*Nemapogon granella* (L.)) (fig. 12) is a small moth about the size of the Angoumois grain moth, creamy white and thickly mottled with brown. The mottled appearance distinguishes it from the Angoumois grain moth. It infests all kinds of grain, both in the field and in storage. The larva feeds on the grain and webs the kernels together.

This moth is distributed throughout the Northern States but is not very abundant and cannot be compared with the Angoumois grain moth for destructiveness.

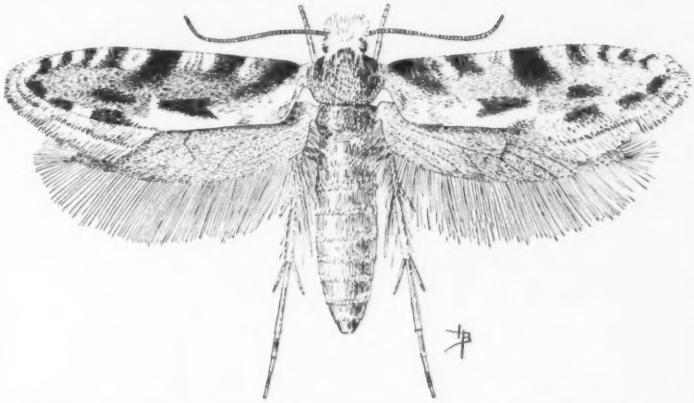

FIGURE 12.—Adult of the European grain moth (*Nemapogon granella* (L.)). The moth has a wing expanse of about one-half inch.

PINK CORNWORM

The pink cornworm (*Pyroderces rileyi* (Wals.)) (fig. 13) is the larva, or caterpillar, of a small moth. It is about five-sixteenths of an inch long when full-grown; pink, with head and thoracic shield pale brown. The moth which develops from this worm or larva is smaller than the Angoumois grain moth, with a wing expanse of slightly less than half an inch. The forewings are banded and mottled with yellow, reddish brown, and black. The pale grayish hindwings are very slender and are edged with long fringes (fig. 14).

This insect is common in the South, where it causes considerable injury to corn, both in the field and in storage. Infestation begins in the field and is continued after the corn is placed in storage. The very characteristic injury is shown in figure 15. The large amount of

FIGURE 13.—The pink cornworm: Full-grown larva, side view, greatly enlarged. When full-grown, the larva is about five-sixteenths of an inch long.

frass that is loosely webbed together and fills the interstices between the kernels or is crowded into the cavities of kernels that have been eaten out is a reliable indication of the presence of this pest. The pearly white eggs are laid singly or occasionally in twos or threes. The pinkish larvae feed on the seed, husk, and cob with equal relish. Though capable of serious injury to corn, in particular as it comes to maturity in the field and while in the cribs on southern farms, the pink cornworm is seldom a serious pest of commercial shipments.

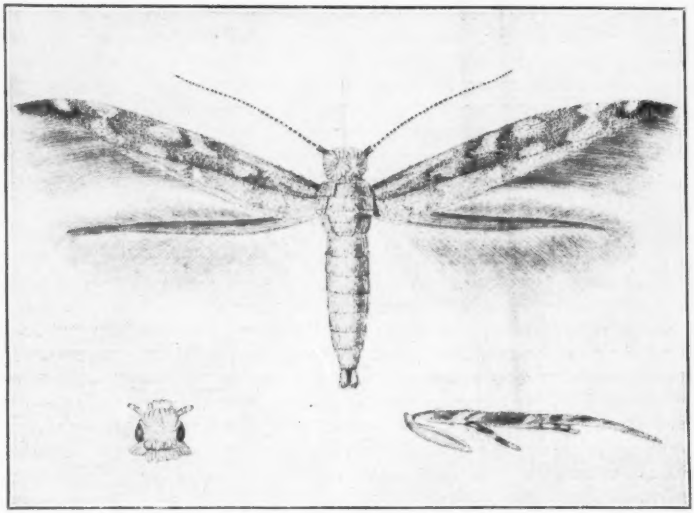

FIGURE 14.—The pink cornworm: Moth, much enlarged; head and leg more enlarged. The moth has a wing spread of a little less than half an inch.

RICE MOTH

The rice moth (*Corcyra cephalonica* (Staint.)) has a wing expanse of about half an inch and is pale grayish brown or tawny. Its characteristic appearance is shown in figure 16. The larva (fig. 17) resembles somewhat that of the Indian-meal moth, being, when full grown, about half an inch long and varying from white to a dirty, slightly bluish gray with occasional tints of green. Damage by the pest, as in the case of all moth pests, is done by the larvae, which are rather general feeders. They attack such materials as rice, cocoa, chocolate, dried fruit, biscuits, and seeds. The larvae produce a dense webbing as they become full-grown. When feeding upon grains, they spin dense silken tubes, webbing the grain kernels into the walls of the tubes. The moths live from 1 to 2 weeks, the females laying between 100 and 200 eggs each. In summer, development from egg to adult covers a period of about 6 weeks. The rice moth has not as yet become very widely disseminated in this country.

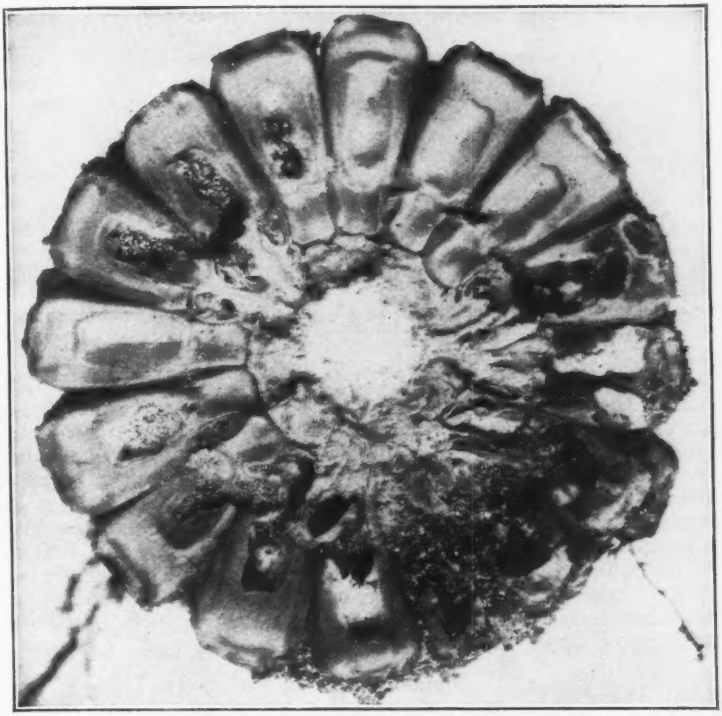

FIGURE 15.—Ear of corn cut to show characteristic feeding and destruction by pink cornworm larvae. Note that the larvae eat from one kernel to another, often severing the kernels from the cob. The larvae sometimes eat into the cob, and there transform to the pupal stage. The pupae are about one-third as long as the kernels shown.

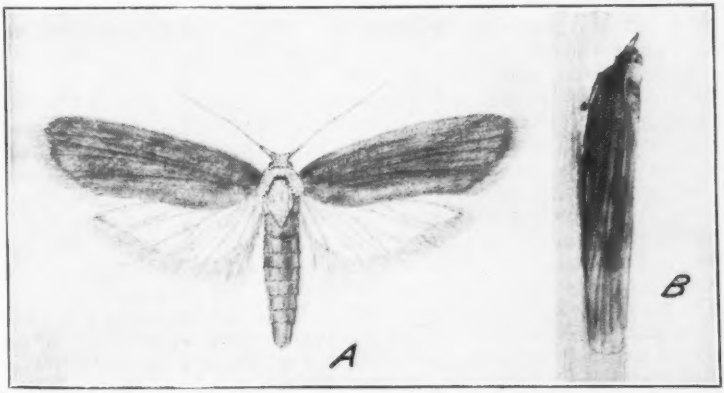

FIGURE 16.—The rice moth: *a*, Mature moth, dorsal view, with wings spread; *b*, side view of same moth with wings folded about body. The moth has a wing spread of about half an inch.

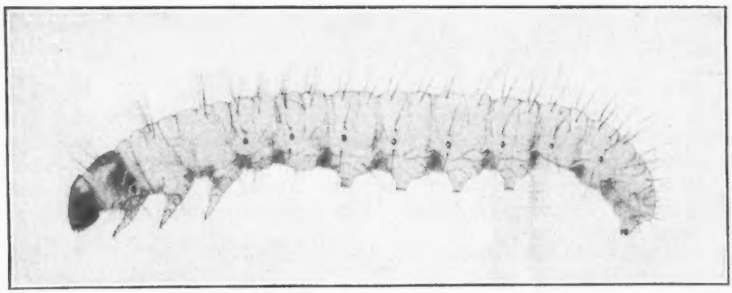

FIGURE 17.—Full-grown larva of the rice moth. The full-grown larva is about one-half inch long.

FLOUR MOTHS

Among the flour moths are some of the commonest and most serious pests of grain products. They are designated as flour moths, not because they feed entirely upon flour or milled products, but because they seldom attack sound kernels. They prefer broken grains, grains injured by major grain pests, and more especially cereal milled products such as flour, breakfast foods, and meals. All three of the flour moths are commonly found in grain warehouses, but the Indian-meal moth and the meal moth are probably the most frequently reported. These two moths may, under exceptionally favorable conditions, become established in whole grain and other seeds and cause injury, especially by eating out the germ.

INDIAN-MEAL MOTH

The Indian-meal moth (*Ploaia interpunctella* (Hbn.)) is a rather handsome moth with a wing expanse of nearly three-fourths of an inch (fig. 18). It is easily distinguished from other grain pests by the peculiar marking of its forewings. These are reddish-brown with a coppery luster on the outer two-thirds, but whitish gray on the inner or body end. The female moths lay from 100 to 300 eggs, singly or in groups, on food material. The eggs hatch within a few days into small whitish larvae or caterpillars. These larvae feed upon grains, grain products, dried fruits, nuts, and a rather wide variety of foodstuffs. When full-grown, the larvae are about half an inch long, dirty white, varying sometimes to greenish and pinkish hues. A full-grown larva is shown in figure 19, clinging to a kernel of wheat. This larva spins a silken cocoon and transforms to a light-brown pupa, from which the parent moth later emerges. The Indian-meal moth may pass through its egg, larval, and pupal stages in from 6 to 8 weeks during warm weather.

The larva of the Indian-meal moth spins a web as it becomes full-grown and leaves behind a silken thread wherever it crawls. When sacks of cracked corn, meal, or corn in the ear that has been previously injured by other pests become heavily infested, this webbing often is sufficiently abundant to attract attention. The loosely clinging web shown on the ear of corn in figure 20 is characteristic of this pest.

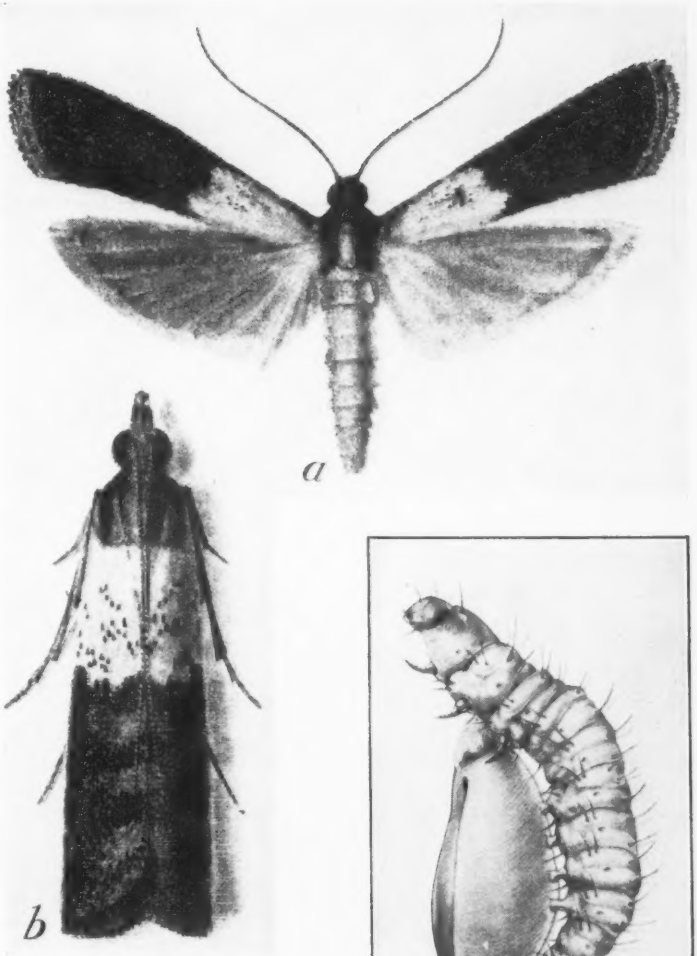

FIGURE 18. — The Indian-meal moth: *a*, Moth with wings spread; *b*, moth with wings folded as ordinarily seen when the moth is resting on some surface in the warehouse. The moth has a wing expanse of nearly three-fourths of an inch.

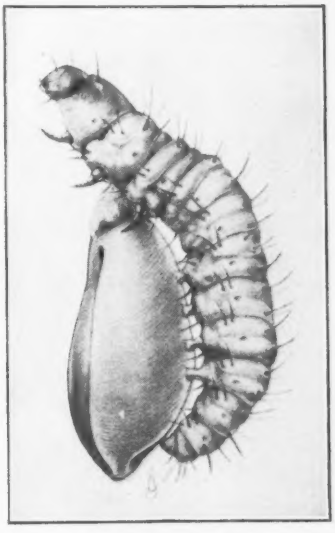

FIGURE 19.—Well-grown larva of the Indian-meal moth, crawling on kernel of wheat.

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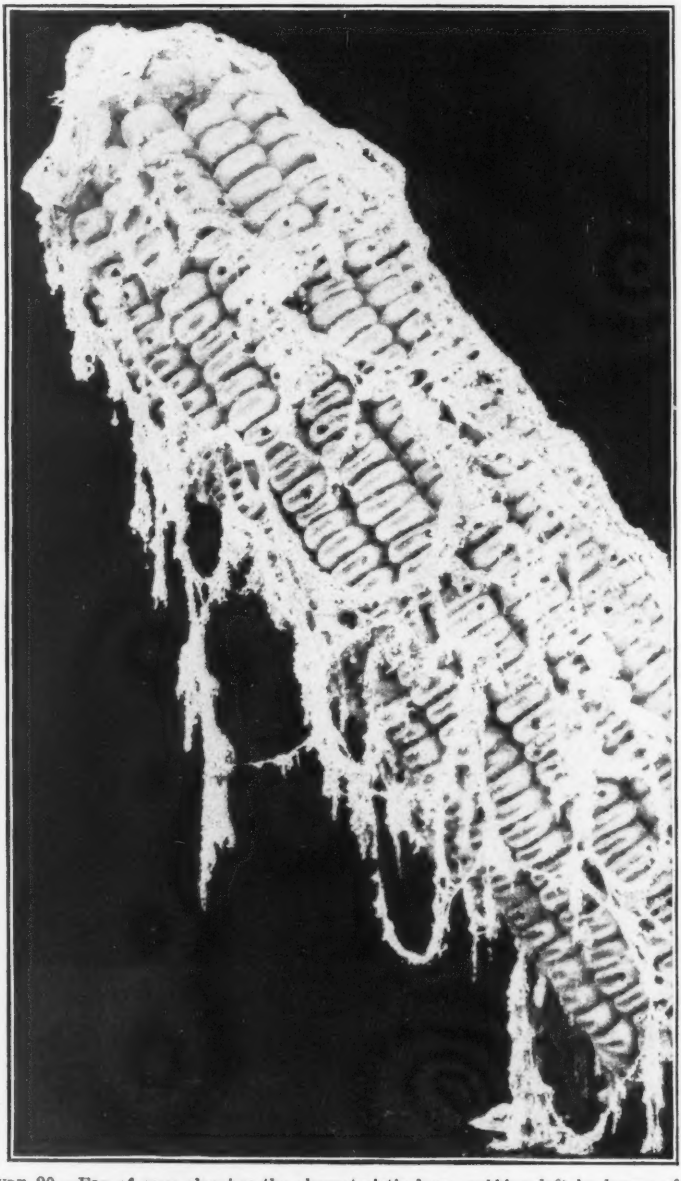

FIGURE 20.—Ear of corn showing the characteristic loose webbing left by larvae of the Indian-meal moth. This moth rarely attacks sound grain, but, as is here shown, frequently attacks grains already injured by other grain pests. Such webbing as is here shown develops only when corn or other grains are left unmoved for some time.

MEDITERRANEAN FLOUR MOTH

The Mediterranean flour moth (*Ephestia kuehniella* Zell.), has a wing spread of slightly less than 1 inch. Its hind wings are a dirty white, but its forewings, which alone show when the moth is not flying, are a pale leaden gray with transverse wavy black markings (fig. 21).

The Mediterranean flour moth is a native of Europe. Its first discovery in the United States was in California in 1892. Since that time it has become widespread over the country and for many years was considered the most troublesome pest of flour mills. The larvae spin silken threads wherever they go, webbing and matting together particles of food in which they are feeding. In flour mills, the machinery sometimes becomes so clogged with the matted flour that milling operations are halted. In mills that have an annual fumigation this insect is no longer a major problem. Although preferring flour and meal, the Mediterranean flour moth attacks grain, bran, cereal products, and many other foodstuffs.

The female moth lays small white eggs in accumulations of flour, meal, or waste grain. From the eggs the small larvae hatch in a few days. When full-grown, these are about half an inch long and are whitish or pinkish, with a few small black spots on the body. The full-grown larva spins a silken cocoon in which the insect transforms to a reddish-brown pupa. Later, the parent moth emerges from the pupa. During warm weather the Mediterranean flour moth requires 8 or 9 weeks to pass through its egg, larva, and pupal stages.

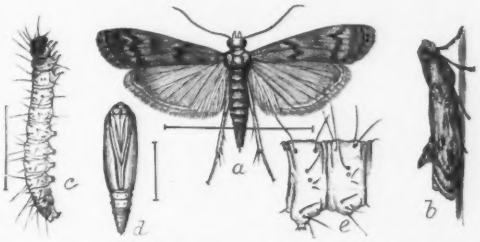

FIGURE 21.—The Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa (enlarged); *e*, abdominal joint of larva (more enlarged). The adult moth has a wing expanse of a trifle less than 1 inch.

Three related species, *Ephestia cautella* (Walk.), *E. elutella* (Hbn.), and *E. figulilella* Gregs., closely resemble the Mediterranean flour moth in appearance and have similar habits. They are general feeders on dried vegetable products, but are rarely abundant enough to cause serious damage to stored cereal products.

MEAL MOTH

The meal moth (*Pyralis farinalis* L.), is brownish and somewhat larger than the Indian-meal moth, though varying in size, usually having a wing spread of about 1 inch. Its forewings are marked in a characteristic pattern, indicated in figure 22; they are light brown with dark-brown patches at the base and tip, and each has two wavy transverse white lines. The meal moth is widely distributed and is a general feeder in the larval stage upon cereals, cereal products, hay, and many types of dried vegetable matter. It is usually

found in damp basements or in other places where accumulations of damp, spoiled grain, bran, or meal are found. While preferring material that is damp and in poor condition, the meal moth may attack and severely damage sound wheat or cereal products if these are stored in moist places or have a relatively high moisture content. This insect sometimes attracts much attention because of its capacity to web up and bind together seeds of various kinds. The larvae cut through burlap sackings and can damage sacks greatly when heavy infestations develop in sacked material. Figure 23 shows the characteristic webbing together of infested seeds—in this instance navy beans—and figure 24 shows the tendency for larvae to spin their

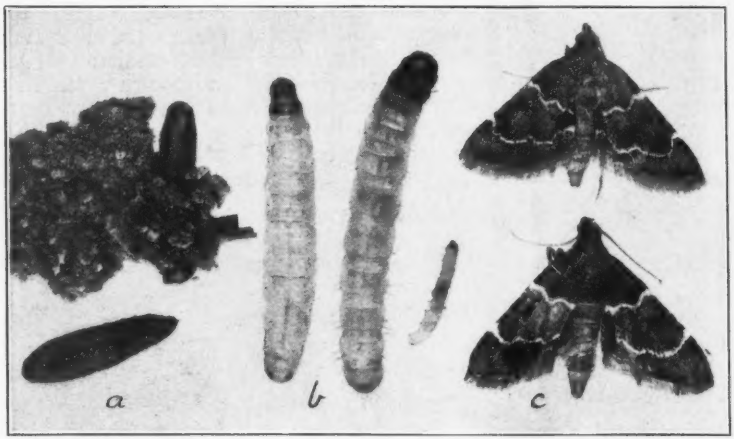

FIGURE 22.—The meal moth: *a*, Pupa and (above) webbed mass of grain showing portion of a pupa protruding; *b*, two well-grown larvae with a smaller larva at right; *c*, two adult moths. Magnified about one and one-half times. The markings on the forewings easily distinguish this insect from other grain pests.

whitish silken cocoons on the outside of grain sacks where the sacks touch one another. When the larvae cut sacks, the seeds fall out and lodge where the sacks touch one another. In such places the seeds are usually heavily infested.

The larvae are whitish and, when full-grown, attain a length of about 1 inch. The two larger larvae in figure 22 indicate the normal shape and show the contrast between the black of the head and the first body segment and the white of the remainder of the body. Often the body of the larva is tinged with orange toward each end. The larvae spin peculiar tubes of silk in which are mixed particles of the food material. They rest in these tubes, which are very tough, and feed from the openings at the ends. When full-grown, the larvae leave the tubes, spin silken cocoons, also often covered with food particles, and transform to the pupae, from which later emerge the adult moths. The female moths live for about a week and lay between 200 and 400 eggs. The developmental period from egg to adult in summer requires from 6 to 8 weeks.

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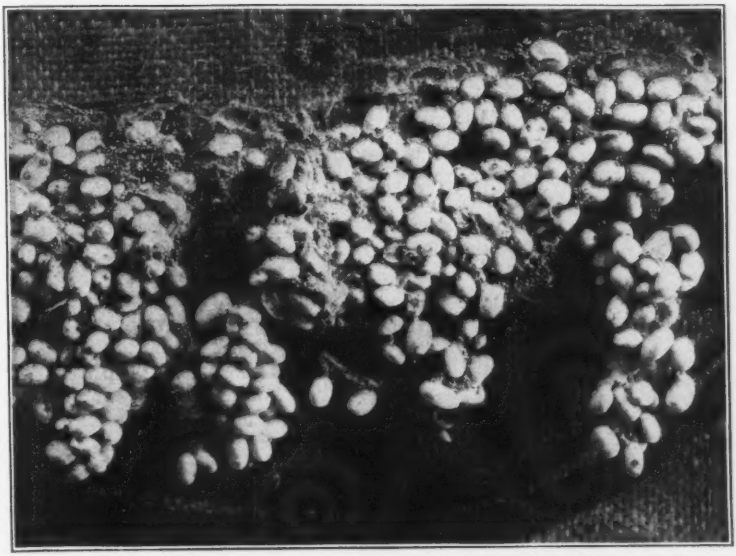

FIGURE 23.—Navy beans webbed together by larvae of the meal moth and adhering to sack.

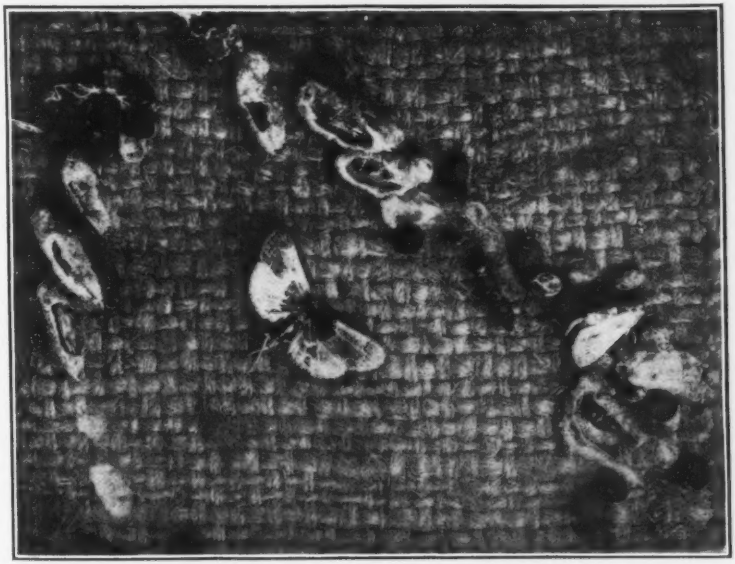

FIGURE 24.—The outside of a grain sack that was filled with infested vetch seed. Note vetch seed sticking to the side of the bag as a result of the webs of the larvae of the meal moth, the numerous whitish cocoons with dark pupae within, and, in the center, one adult moth. Natural size.

GRAIN AND FLOUR BEETLES

CADELLE

The cadelle (*Tenebroides mauritanicus* (L.)) is an elongate, oblong, flattened, black or blackish beetle about one-third of an inch long (fig. 25). It is sometimes called the bolting-cloth beetle because of its habit of cutting the silk cloths of bolting reels and redressing machines in flour mills.

The larva of the cadelle is one of the largest of the grain-infesting insects and is easily recognized. It is about three-fourths of an inch long, fleshy, with the abdomen terminating in two dark horny points. The larva is a dirty or chalky white, with head, thoracic shield, and the two horny points at the end of the body black.

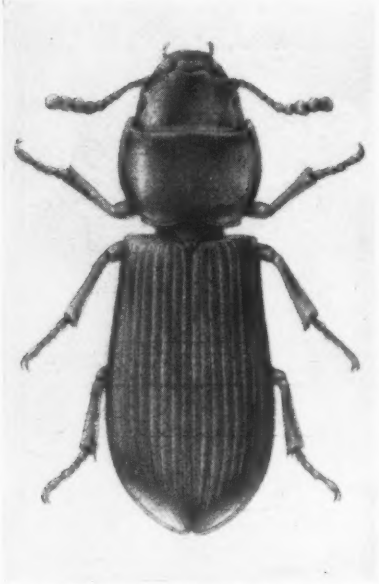

FIGURE 25.—The cadelle. This beetle is about one-third of an inch long.

This insect is widespread over the world and is frequently found in mills, granaries, and storehouses, where it infests flour, meal, and grain. Both larva and adult feed on grain and have the destructive habit of going from kernel to kernel and devouring the germ. The cadelle is one of the longest-lived of the insects that attack stored grain; many of the adults live for more than a year and some of them for nearly 2 years. The female beetles oviposit during the greater part of their lives and under favorable conditions will lay about 1,000 eggs each.

The white eggs are laid in clusters in the food material and hatch in from 7 to 10 days in warm weather. The larvae complete their growth in from 2 to 14 months, then seek some secluded place in which to transform to the pupal stage (fig. 26), frequently boring into the timbers of the bin or other receptacle that holds the infested material. Both larvae and adults can live for considerable periods without food, frequently remaining hidden in the woodwork of the bins for a long time after the grain has been removed. When new grain is put into such a bin it becomes infested in a surprisingly short time.

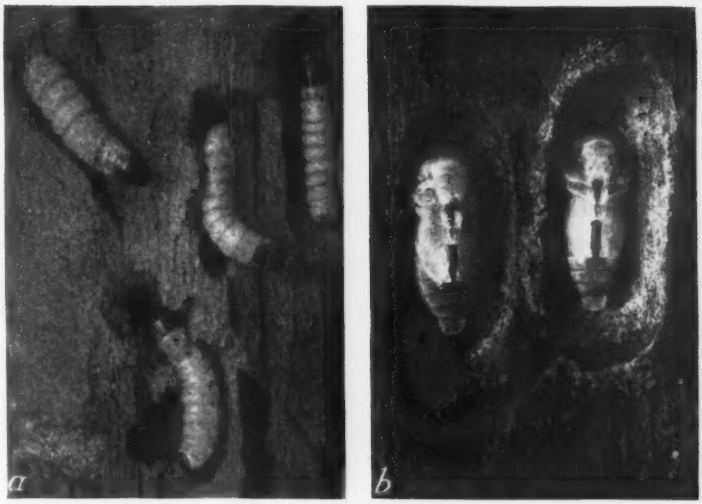

FIGURE 26.—Larvae and pupae of the cadelle: The larvae (*a*) are shown in the galleries they have made in a piece of timber, and the pupae (*b*) in cells hollowed out where two boards were in contact.

SAW-TOOTHED GRAIN BEETLE

The saw-toothed grain beetle (*Oryzaephilus surinamensis* (L.)) is one of the best-known of the cosmopolitan grain pests. A slender, flat, brown beetle about one-tenth of an inch long, it gains its name from the peculiar structure of the thorax, which bears six saw-tooth-like projections on each side (fig. 27). It attacks in both its larval and adult stages all food of vegetable origin, especially grain and such grain products as flours, meals, breakfast foods, stock and poultry feeds, copra, nut meats, candies, and dried fruits.

The adults live, on an average, from 6 to 10 months, but some individuals may live as long as 3 years. The female beetles have been known to lay from 43 to 285 eggs, dropping them loosely among the foodstuff or tucking them away in a crevice in a kernel of grain. The small, slender, white eggs hatch in from 3 to 5 days. The emerging larvae do not spend their lives within a single grain, but crawl about actively, feeding here and there. They become full-grown (fig. 27, *a*) in about 2 weeks during summer weather and then construct delicate cocoonlike coverings by joining together small grains or fragments of foodstuffs with a sticky secretion. Within this cell the larva changes to the pupal stage, which lasts about a week. Development from egg to adult may take place in from 3 to 4 weeks in summer.

Two closely related species occur in this country, *Oryzaephilus bicornis* (Er.), and the merchant grain beetle (*O. mercator* (Fauv.)). They closely resemble the saw-toothed grain beetle in appearance and habit and are easily confused with it. The first-named differs from *surinamensis* chiefly in that the side margins of the front in the male are more strongly reflexed, forming promi-

nent, pointed, earlike horns. *O. mercator* differs in appearance from *O. surinamensis* chiefly because of much narrower, more sharply projecting temples.

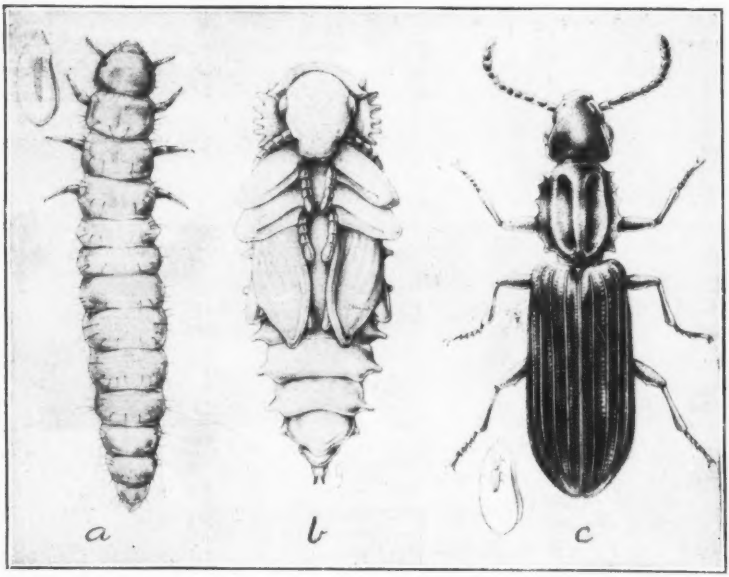

FIGURE 27.—The saw-toothed grain beetle: *a*, Well-grown larva; *b*, pupa; *c*, adult beetle. The adult beetle is about one-tenth of an inch in length. Beside the larva and adult are shown grains of wheat with the relative size of the insect indicated on them.

SQUARE-NECKED GRAIN BEETLE

The square-necked grain beetle (*Cathartus quadricollis* (Guér.)), is closely related to the saw-toothed grain beetle, which it greatly resembles in form, size, and color. It is a flattened, oblong, polished, reddish-brown beetle about one-tenth of an inch long. It differs from the saw-toothed grain beetle by having the thorax almost square and in lacking the saw-toothlike projections (fig. 28).

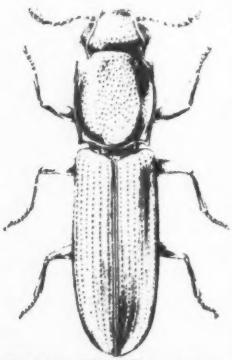

FIGURE 28.—The square-necked grain beetle. The adult beetle is about one-tenth of an inch long.

This beetle is chiefly abundant in the South, where it is found in great numbers outdoors infesting the seed pods of a great variety of plants. It is one of the most common beetles in stored corn in the South and in the cornfields is always to be found on damaged or exposed ears. The immature stages closely resemble those of the preceding species both in form and in habit. The larvae have the bad habit of devouring the germ of the seed in which they breed. They can develop from egg to adult in about 3 weeks.

FIGURE 29.—The foreign grain beetle.

FOREIGN GRAIN BEETLE

The foreign grain beetle (*Ahasverus advena* (Waltl.)) is a small reddish-brown beetle somewhat similar in appearance to the preceding species, to which it is closely related. It differs from it by being smaller and more robust (fig. 29). Although of world-wide distribution, it is of little consequence as an enemy of stored grains. It is attracted to damp and moldy grains and feeds on the molds developing in such grains. It is rarely found in clean grain.

MEXICAN GRAIN BEETLE

The Mexican grain beetle (*Pharaxonotha kirschi* Reitt.) (fig. 30) is a highly polished, deep-brown beetle about three-sixteenths of an inch long. While resembling somewhat the confused flour beetle in general appearance, it can be readily distinguished by its more polished surface and by its longer antennae.

This insect is common in Mexico and Guatemala, where it breeds in grain and grain products. It was found in this country in grain exhibits at the World's Columbian Exposition but is not known to be permanently established in this country as yet. It may be found in grain in the extreme South.

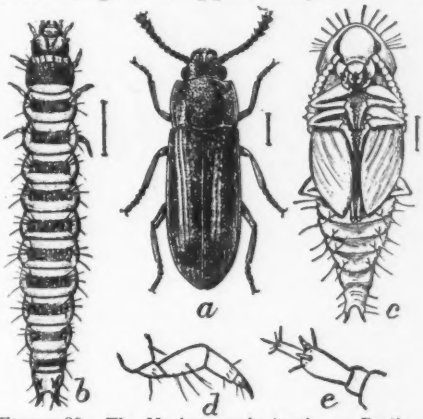

FIGURE 30.—The Mexican grain beetle: *a*, Beetle; *b*, larva; *c*, pupa; *d*, leg of larva; *e*, antenna of larva. *a*, *b*, *c*, enlarged about 8 times; *d*, *e*, greatly enlarged.

SIAMESE GRAIN BEETLE

The Siamese grain beetle (*Lophocateres pusillus* (Klug)) is a flattened, reddish-brown beetle slightly less than an eighth of an inch long, characterized by the much flattened margins of the thorax and wing covers (fig. 31).

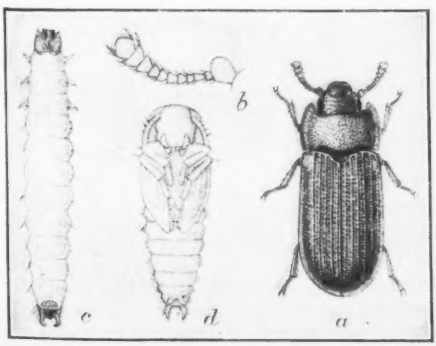

FIGURE 31.—The Siamese grain beetle: *a*, Beetle; *b*, antenna of same; *c*, larva; *d*, pupa. *a*, *c*, *d*, about 10 times natural size; *b*, about 30 times natural size.

First appearing in this country in exhibits of rice and cereals from Siam, Liberia, and Ceylon at the World's Columbian Exposition, it is now well-established in the Southern States. It is commonly found in rice mills in Texas but does not cause serious damage.

FLAT GRAIN BEETLE

The flat grain beetle (*Laemophloeus minutus* (Oliv.)) (fig. 32), as its scientific name would indicate, is one of the smallest beetles commonly found in stored grain. It is a minute, flattened, oblong, reddish-brown beetle about one-sixteenth of an inch long, with elongate antennae about two-thirds as long as the body. It is cosmopolitan in distribution and is one of the commonest insect pests of stored grain. It is not a primary pest of stored grain, however, and the adult is apparently unable to survive in sound, uninjured grain. It follows up the attack of the more vigorous grain pests and is frequently found in enormous numbers associated with the rice weevil. It is a scavenger by nature and often infests grain and meal that is out of condition.

FIGURE 32.—Adult of the flat grain beetle, showing characteristic long antenna. Body not more than one-sixteenth of an inch long.

The small white eggs are placed in crevices in the grain or dropped loosely in farinaceous material. The larvae are particularly fond of the germ in wheat, and in infested grain many kernels will be found uninjured except for the removal of the germ. The larvae also feed on dead insects. When fully grown, the larvae form cocoons of a gelatinous substance to which food particles adhere. They transform to the pupal stage in these cocoons and later emerge as adults. Under favorable conditions this insect may complete its development from egg to adult in about 5 weeks, although the average length of the developmental period in summer is about 9 weeks.

A related beetle, *L. turcicus* Grouv., resembles the preceding species so closely in appearance and habit that it is usually confused with it. It also is cosmopolitan in distribution. The females of the two species are so much alike that it is almost impossible to distinguish between them. The males, however, can be distinguished by the length of the antennae. In *L. turcicus* the antennae of the male beetles are as long as or longer than the body, whereas in *L. minutus* the antennae of the males are only two-thirds the length of the body.

RUST-RED GRAIN BEETLE

A third species, *Laemophloeus ferrugineus* (Steph.), known as the rust-red grain beetle, is similar to the two preceding species in appearance and habit, but differs in that the antennae of the male beetle are not more than half as long as the body. This species is more resistant to cold weather than the other two species and is more commonly found in stored grain in the Northern States.

CONFUSED FLOUR BEETLE

The confused flour beetle (*Tribolium confusum* Jacq.-Duv.) (fig. 33) is a shiny, reddish-brown beetle about one-seventh of an inch long, flattened and oval, with head and upper parts of thorax densely covered with minute punctures and with wing covers ridged lengthwise

and sparsely punctured between the ridges. It is generally distributed over the world and is very abundant in all parts of this country. It is a general feeder on farinaceous material and is undoubtedly the most abundant and injurious insect pest of flour mills in the United States. It is found in granaries, mills, warehouses, and everywhere where grain or grain products are stored.

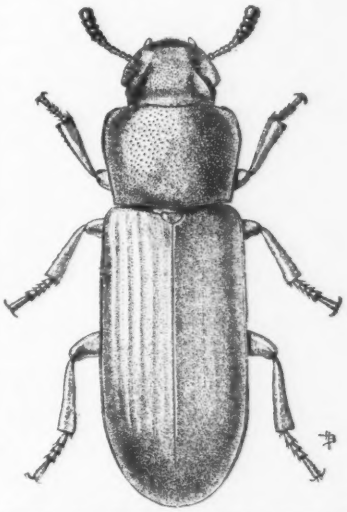

FIGURE 33.—The confused flour beetle is undoubtedly more troublesome in flour mills than any other insect except the closely related rust-red flour beetle. The beetle is about one-seventh of an inch long.

The average life of the beetles is about 1 year, but some have been known to live as long as 3 years 9 months. The females lay an average of about 450 eggs each. The small white eggs are laid loosely in flour or other food material in which the adults are living. They are covered with a sticky secretion and thus become covered with flour or meal, and readily adhere to the sides of sacks, boxes, and other containers, so that fresh material placed in them is rapidly infested. The eggs hatch in from 5 to 12 days into small wormlike larvae, slender, cylindrical, and wiry in appearance. When fully grown they are about three-sixteenths of an inch long, and are white, tinged with yellow. These larvae feed on flour or other material such as grain dust and the broken surfaces of grain kernels. When full grown they transform to small naked pupae. At first white, the pupae gradually change to yellow and then brown, and shortly afterwards transform to beetles. The period from egg to adult in summer averages about 6 weeks under favorable weather conditions, though the life cycle is greatly prolonged by cold weather, as is true of all grain pests.

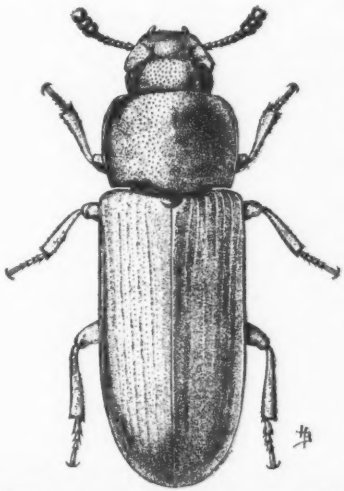

FIGURE 34.—The rust-red flour beetle. The beetle is about one-seventh of an inch long.

RUST-RED FLOUR BEETLE

The rust-red flour beetle (*Tribolium castaneum* (Herbst)) is almost identical in appearance with the preceding species, to which it is closely related. It can be distinguished from the confused flour beetle only with the aid of a mag-

nifying glass. The segments of the antennae of the confused flour beetle increase in size gradually from the base to the tip, whereas in the rust-red flour beetle the last few segments of the antennae are abruptly much larger than the preceding ones, giving the antennae the appearance of being suddenly enlarged at the tip. In addition, the margins of the head of the confused flour beetle are expanded and notched at the eyes, whereas the margins of the head of this species are nearly continuous at the eyes. The differences between the two species are clearly shown in figures 33 and 34. This insect is constantly found associated with the confused flour beetle and has similar feeding and breeding habits. The immature stages of the two insects are so nearly alike that it is impossible to distinguish between them. The developmental period from egg to adult is usually somewhat shorter than for the preceding species. Although cosmopolitan in distribution, the rust-red flour beetle is found more commonly in the South, where it causes very serious damage to grain products. In addition to the actual damage caused by its feeding activities, it imparts a nauseous smell and taste to the material it infests. Like the confused flour beetle, the rust-red flour beetle is primarily a pest of milled products; while present in grain shipments, it confines its attack in these to grain dust and the surface of broken grains, hence is not a primary pest of commercial shipments.

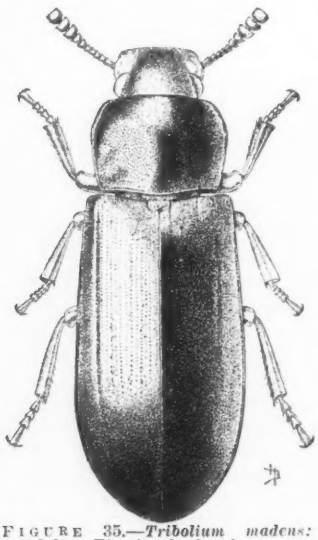

FIGURE 35.—*Tribolium madens:* Adult. The beetle is about one-sixth of an inch in length.

BLACK FLOUR BEETLE

The black flour beetle (*Tribolium madens* (Charp.)) (fig. 35), is another species of the genus *Tribolium* that occurs in the United States. Not so well known as the two preceding species, it has similar habits and is occasionally found infesting grain and grain products in flour mills and storehouses. It is seldom found in injurious numbers and is by no means as widespread as *T. confusum* and *T. castaneum*. It occurs in its greatest abundance in the States of the Rocky Mountain region, but it has been reported from widely scattered points over the country. It may be readily distinguished from the confused and rust-red flour beetles by its being black and by its larger size. It is about one-sixth of an inch in length. *T. destructor* Uyttenb., another species of this destructive group of flour beetles, has recently been reported from Montreal, Canada, infesting poultry feed. It is an introduction from Europe.

LONG-HEADED FLOUR BEETLE

The long-headed flour beetle (*Latheticus oryzae* Waterh.) (fig. 36) is a slender, flattened beetle, slightly less than an eighth of an inch long, somewhat similar in form to the confused flour beetle but narrower and pale yellowish brown. It is further differentiated by the peculiarly shaped antennae and by the minute canthus behind each eye. It has been reported from most parts of the world as infesting wheat, rice, corn, barley, rye flour, and similar products. It was first recognized in this country from specimens collected in Texas in 1908. It is now widespread in the Southern and Middle Western States, where it is common in rice and flour mills, infesting grain and grain products and causing the same type of damage as does the confused flour beetle.

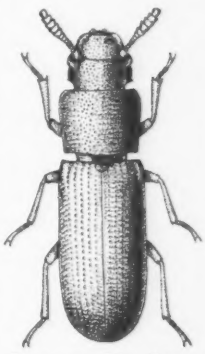

FIGURE 36.—Long-headed flour beetle. The beetle is slightly less than one-eighth of an inch long.

BROAD-HORNED FLOUR BEETLE

The broad-horned flour beetle (*Gnathocerus cornutus* (F.)) owes its name to the peculiar structure of the mandibles, or jaws, of the male beetle, which are armed with a pair of broad, stout horns, as shown in figure 37. It is a robust, reddish-brown beetle, about one-sixth of an inch long, closely resembling the other flour beetles in appearance, but easily distinguished by the peculiar structure of the jaws. It is cosmopolitan in distribution and is common in

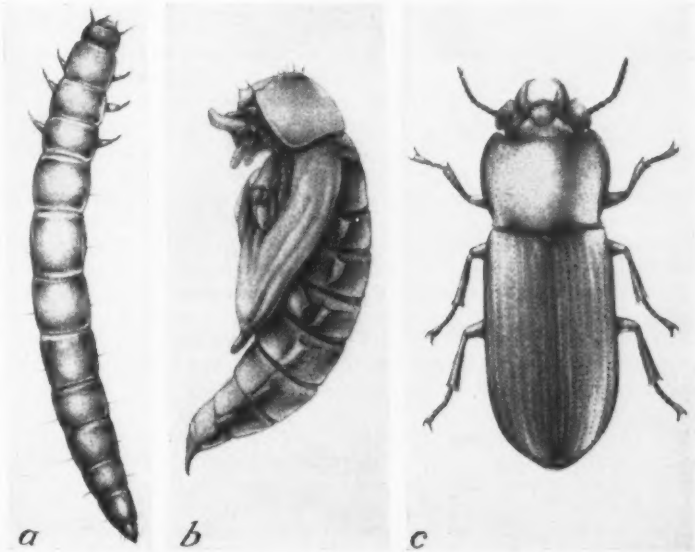

FIGURE 37.—The broad-horned flour beetle: *a*, Larva; *b*, pupa; *c*, adult. The beetle is about one-sixth of an inch long.

all parts of the United States except in the Great Plains, where it is comparatively rare. It prefers to feed in flour and meal, but is found in a variety of grains. The adult beetles frequently live for a year or longer, the females laying from 100 to 200 eggs each. The small white eggs hatch in from 4 to 6 days in warm weather, and development from egg to adult takes place in from 6 to 8 weeks.

SLENDER-HORNED FLOUR BEETLE

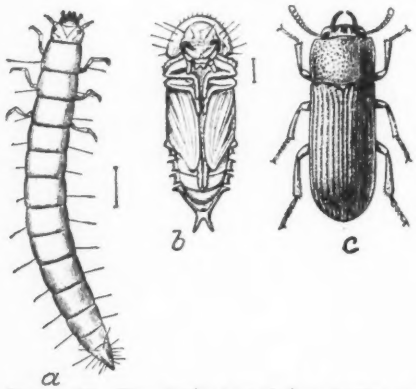

FIGURE 38.—The slender-horned flour beetle: *a*, Larva; *b*, pupa; *c*, beetle. The beetle is about one-eighth of an inch long.

The slender-horned flour beetle (*Gnathocerus maxillosus* (F.)) is closely related to the preceding species and is of similar form and appearance. It is about one-eighth of an inch in length, and, in addition to its smaller size, it may be distinguished from the broad horned flour beetle by the shape of the horns with which the mandibles or jaws of the male are armed. In this species (fig. 38) the horns are slender and incurved. Its habits are similar to those of the preceding species. It is less common in the United States than *G. cornutus* and is more or less confined to the Southern States.

SMALL-EYED FLOUR BEETLE

The small-eyed flour beetle (*Palorus ratzeburgi* (Wissm.)) (fig. 39), is the smallest of the so-called flour beetles that infest grain and grain products in this country. It is a tiny, flattened, shiny, reddish-brown beetle, somewhat oblong in form and measuring about one-tenth of an inch in length. It occurs throughout the world and is widely distributed in this country. It breeds in grain and milled products and is frequently found in flour-mill basements.

FIGURE 39.—The small-eyed flour beetle. The beetle is about one-tenth of an inch long.

DEPRESSED FLOUR BEETLE

The depressed flour beetle (*Palorus subdepressus* Woll.) is very similar in appearance and habits to the small-eyed flour beetle. It may be distinquished from this species by its slightly larger size and by the fact that the sides of the front of the head are strongly reflexed and extend backward, concealing the front portion of the eye. In the small-eyed flour beetle the sides of the front do not extend backward. The depressed flour beetle, also, is cosmopolitan in distribution but is much less common in the United States than *P. ratzeburgi* except perhaps in the Great Plains.

EGGS OF FLOUR AND GRAIN INSECTS

The eggs of the common flour- and grain-infesting insects are rarely seen by the layman. They are usually white in color and are often covered with a sticky substance that causes particles of flour or other material to adhere to them, thus making them difficult to distinguish from the foodstuff in which they are deposited. Some are oval or oblong-oval, while others are slender and spindle shaped. Their small size is well illustrated in figure 40, in which is shown a group of eggs of four different species of insects resting on a piece of 10XX silk bolting cloth. The eggs of the flat grain beetle are so small that if placed side by side they would average about 150 to the inch. Those of the cadelle, which is one of the larger beetles infesting stored cereal products, if laid end to end, would average about 19 to the inch. During the process of milling flour and preparing it for the market it is sifted through silk bolting cloth to remove insect eggs and other impurities.

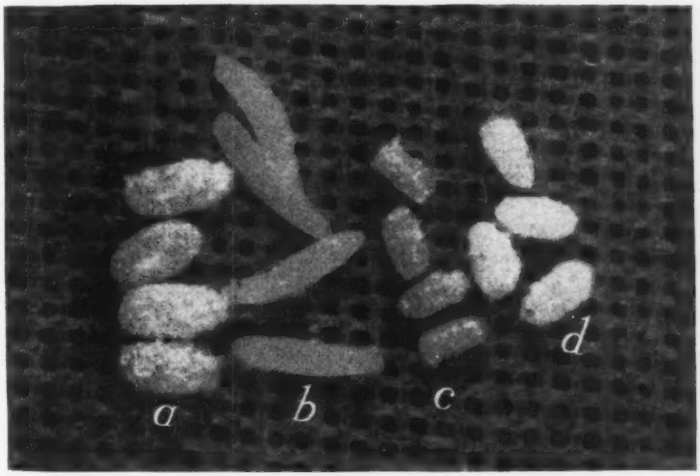

FIGURE 40.—Eggs of flour and grain insects shown resting on a piece of 10XX bolting cloth: *a*, Broad-horned flour beetle; *b*, cadelle; *c*, Mediterranean flour moth; *d*, confused flour beetle. Magnified 20 diameters.

MEALWORMS

The term "mealworm" is applied to the larvae of several beetles of the family Tenebrionidae that are nocturnal in habit and frequent dark places. They breed in refuse grain and coarse cereal and mill products that accumulate in dark corners, under sacks, in bins, and in similar places. They are fond of moist situations and are often found among bags that are slightly damp.

YELLOW MEALWORMS

The yellow mealworm (*Tenebrio molitor* L.) is one of the largest of the insects that infest stored cereal products. It is cosmopolitan in distribution, but, although found occasionally in all parts of the country, it is found in abundance only in the Northern States.

The adult is a polished dark-brown or black beetle, somewhat more than half an inch long, with its thorax finely punctured and with its wing covers longitudinally striated or grooved. The females lay bean-shaped white eggs covered with a sticky secretion that causes the flour, meal, or grain waste in which they are placed to adhere to them. The eggs hatch in about 2 weeks into slender white larvae, which soon turn yellow and assume the form shown in figure 41. When full-grown, the larvae are about an inch long and yellowish, shading to yellowish brown toward each end and at the articulation of each segment. It is to the yellow color of the larva that this insect owes its name of "yellow mealworm."

There is but one generation each year. The adults begin to appear in the latitude of Washington, D. C., in the latter part of May and early in June and may be found until late in August. The female beetles are quite prolific and may lay as many as 500 eggs each. The larvae become full-grown in about 3 months, but instead of transforming then to the adult stage they continue feeding and molting until cold weather and then hibernate as larvae. In late spring or early summer of the following season they transform to the pupal stage, in which stage the insect passes about 2 weeks. Because the yellow mealworm has but one generation each year and is entirely an external feeder upon grains, it need not be feared as a

FIGURE 41.—The yellow mealworm. Four well-grown larvae, two pupae, and the black adult beetle, with five kernels of wheat to indicate relative size. The larvae when full-grown are about 1 inch long and yellowish. The adult beetles are slightly more than half an inch long.

serious pest. Screening and fanning will remove it easily from grain shipments. The well-grown larvae, however, can do serious injury to whole grains under certain conditions when grain is held for long periods without being moved.

DARK MEALWORM

The dark mealworm (*Tenebrio obscurus* F.) is very similar in form, size, and color to the yellow mealworm, to which it is closely related. The adult beetle differs, however, in being dull pitchy black, in contrast to the shiny or polished dark brown or black of the yellow mealworm. Its larva so closely resembles the larva of the yellow mealworm that it can be distinguished most easily by its much darker color.

The two species of mealworms are often found associated, since they have similar feeding habits. The overwintering larvae of the dark mealworm begin to pupate earlier in the season than the yellow mealworms, and the adult beetles emerge during April and May in the vicinity of Washington.

LESSER MEALWORM

The lesser mealworm (*Alphitobius diaperinus* (Panz.)) resembles the two preceding species in form and color but is considerably smaller. It is black or a very dark reddish brown and measures from three-sixteenths to four-sixteenths of an inch in length. The larva is yellowish brown and closely resembles young larvae of the yellow mealworm in form and appearance. It is cosmopolitan in distribution and is commonly found in flour-mill basements in damp or musty flour or grain. It prefers grain and cereal products that are slightly out of condition.

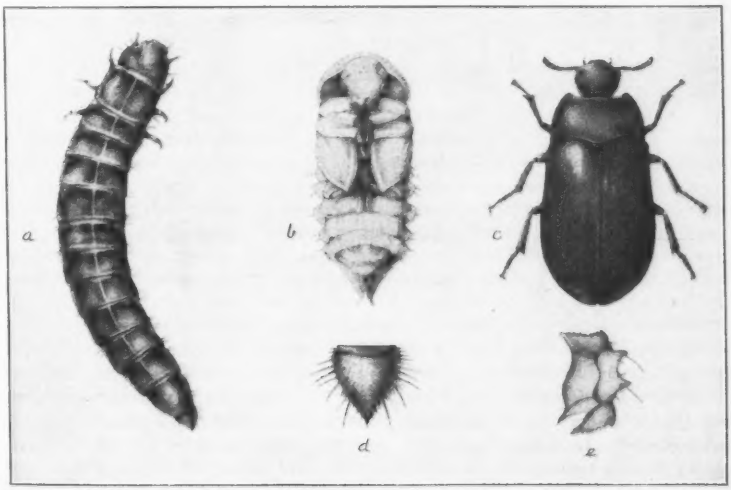

FIGURE 42.—The black fungus beetle: *a*, Larva; *b*, pupa; *c*, adult; *d*, caudal segment of larva; *e*, lateral plate of pupa. The larva is about 1 inch long.

BLACK FUNGUS BEETLE

The black fungus beetle (*Alphitobius piceus* (Oliv.)) (fig. 42) is almost identical in appearance with the lesser mealworm and has similar habits. It prefers grain and cereal products that are damp and moldy and does not cause serious damage to sound grain. It may be distinguished from the preceding species by the fact that the sides of the thorax are curved and the surface coarsely and profusely punctured, whereas in the lesser mealworm the sides of the thorax are nearly straight and the surface finely and sparsely punctured. In the United States it is much less abundant than the lesser mealworm.

DERMESTID BEETLES

The dermestids are a group of beetles that in general are scavengers and feeders on animal matter. Certain species, however, belonging to the genera *Trogoderma*, *Anthrenus*, and *Attagenus* have acquired the habit of varying their diet by feeding at least in part on farinaceous materials. They are of frequent occurrence in flour mills, farm granaries, warehouses, and similar places where grain and grain products are stored.

BLACK CARPET BEETLE

The black carpet beetle (*Attagenus piceus* (Oliv.)) is a small oval beetle between two-sixteenths and three-sixteenths of an inch long. The head and thorax are black, but the wing covers may be either black or dark reddish brown, and clothed with short hairs. Its legs and antennae are dark yellow. The larva is very characteristic and can be readily recognized. It is reddish or golden brown, clothed with short, scalelike, appressed hairs and provided with a tuft of long hairs at the end of the body, as shown in figure 43.

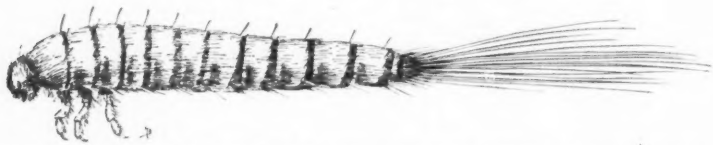

FIGURE 43.—Larva of the black carpet beetle. The larva, including the tuft of hairs, is about two-fifths inch long.

As the name indicates, this insect injures carpets, but in addition it is frequently found infesting stored grain and cereals, both whole and ground. It is usually found associated with other grain-infesting insects, and since it does not thrive on a purely vegetable diet it supplements its diet by occasionally feeding on their dead bodies. The larvae are often to be found in abundance breeding in cracks in the floors of warehouses where foodstuffs have accumulated. In the spring these larvae transform to adults which swarm over bagged material stored there. The larvae of the black carpet beetle develop slowly, so that there is only one generation a year. If conditions are unfavorable the life cycle may be prolonged to 2 or 3 years. The adults which emerge in the spring and early part of the summer live from 2 to 4 weeks, and the females may lay about 100 eggs. It is cosmopolitan in distribution.

LARGER CABINET BEETLE

The larger cabinet beetle (*Trogoderma versicolor* (Creutz.)) is a small, oval beetle about one-eighth of an inch long, its ground color black mottled with reddish brown, covered with gray and light-brown scalelike hairs forming a distinct pattern on the wing covers. The larva somewhat resembles that of the black carpet beetle in appearance. It is about one-eighth of an inch long, reddish brown above and whitish beneath, with body covered with short yellowish-brown hairs and with a tuft of short hairs at the tail end (fig. 44). It is well known for its habit of breeding in dead insects and animal substances and is a serious pest in seed collections. It is one of the few dermestid beetles that seem to thrive on a wholly vegetable diet. The adults are to be found in heated buildings throughout the year. The females may lay as many as 180 eggs, although the average is about 50. The complete life cycle from adult to adult may take about 3 months under favorable conditions. The adults live from 2 to 4 weeks.

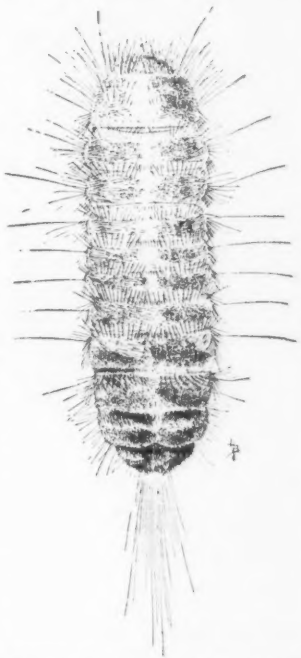

FIGURE 44.—Larva of the larger cabinet beetle. The larva is about one-eighth of an inch long.

VARIED CARPET BEETLE

The varied carpet beetle (*Anthrenus verbasci* (L.)) is somewhat similar in appearance to the larger cabinet beetle but smaller and of different color. It ranges in length from one-sixteenth to two-sixteenths of an inch, and is black with yellowish-white scales that form a broad band across the back and give the body a mottled appearance. The habits of the adult and early stages of this insect are similar to those of the larger cabinet beetle. It is occasionally found in flour mills and granaries, where it infests grain and grain products. The larva is shown in figure 45.

SPIDER BEETLES

Several species of beetles belonging to the family Ptinidae are occasionally found infesting grain and cereal products and attract attention by their peculiar spiderlike form. They are rather widespread in distribution but are rarely abundant enough in the United States to cause serious damage.

HAIRY SPIDER BEETLE

The hairy spider beetle (*Ptinus villiger* (Reit.)) (fig. 46) is a reddish-brown beetle marked with four irregular white patches. It is about one-seventh of an inch long. It is a rather common pest in

the prairie Provinces of Canada and is occasionally destructive in the adjoining Northern States. It attacks stored grain and all types of ground cereal products. The adult beetles appear in warehouses in the spring and lay their eggs in flour, feed, or other cereal products. The female beetles have been observed to lay about 40 eggs. Under favorable conditions development from egg to adult takes place in about 3½ months. The full-grown larvae construct characteristic pupal cases of a silky material covered with particles of the food material in which they occur.

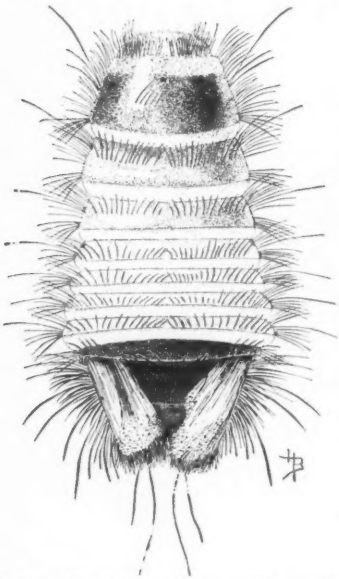

FIGURE 45.—Larva of the varied carpet beetle. The larva is usually about three-sixteenths of an inch long.

BROWN SPIDER BEETLE

The brown spider beetle (*Ptinus brunneus* Dufts.) closely resembles the preceding species in size, color, general appearance, and habits. It may be distinguished from the white-marked spider beetle by the fact that the white markings of the wing covers are lacking.

OTHER SPIDER BEETLES

The Australian spider beetle (*Ptinus tectus* Boield.) has been reported from the United States but is rarely found here. It is very similar in general appearance and habits to the preceding species.

WHITE-MARKED SPIDER BEETLE

The white-marked spider beetle (*Ptinus fur* L.) (fig. 47) is also found in the Northern States and is somewhat more abundant than the preceding species, which it resembles closely in appearance and habits. It is an omnivorous feeder, attacking flour, feed, grain, and miscellaneous foodstuffs. It is rarely abundant enough to cause serious damage.

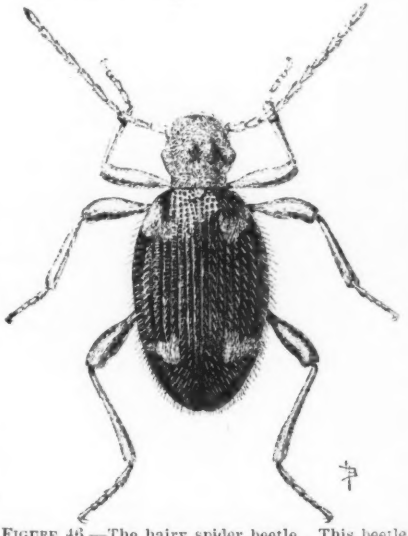

FIGURE 46.—The hairy spider beetle. This beetle is about one-seventh of an inch long.

Mezium americanum (Laporte) (fig. 48) is a small spider beetle of striking appearance. It has a shining subglobular body that distinguishes it from the preceding species. It appears to be somewhat of a scavenger, feeding on dried animal products as well as on organic material. It is not important as a pest of stored grain or grain products, but is occasionally found in mills, warehouses, and dwellings. A closely related species, *Gibbium psylloides* Czemp., resembles it closely in appearance and habits and is found in similar situations. It may be distinguished from it by the fact that the head and thorax are entirely bare while in *M. americanum* the head and thorax are densely covered with small scales and scalelike hairs.

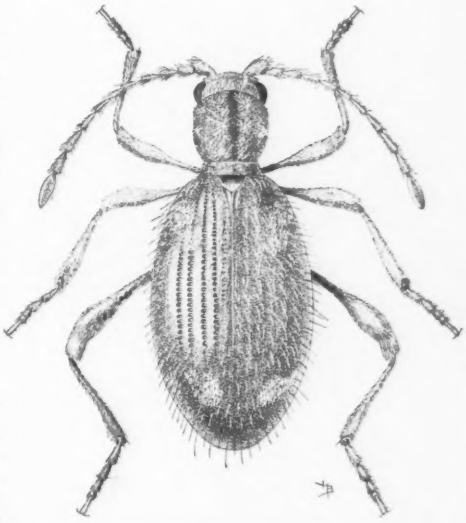

FIGURE 47.—The white-marked spider beetle, adult female. (The male is elongate oval and is not so conspicuously marked as the female.)

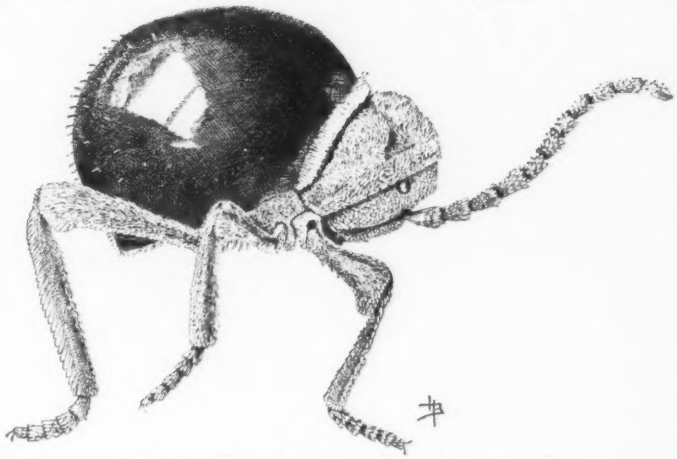

FIGURE 48.—*Mezium americanum*, adult beetle. × 20.

MISCELLANEOUS BEETLES

TWO-BANDED FUNGUS BEETLE

The two-banded fungus beetle (*Alphitophagus bifasciatus* (Say)) is a handsome little elongate-oval beetle slightly less than an eighth of an inch long. It is reddish brown with two broad black bands across the wing covers. Its characteristic color pattern is shown in figure 49. It is distributed over the world and is in general a feeder on fungi and molds, being a scavenger in refuse grain and grain products, decaying vegetable matter, etc. It is frequently found around mills and storehouses where waste material is allowed to accumulate. The larvae have been reared from moist corn meal and in spoiled cereals. The insect is often found in the holds of grain ships in wet or damaged grain.

FIGURE 49.—The two-banded fungus beetle, adult ×10.

CORN SAP BEETLE

The corn sap beetle (*Carpophilus dimidiatus* (F.)) may be readily recognized by its peculiar wing covers, which are short and truncate, leaving the tip of the abdomen exposed, as shown in figure 50. It is a small, dark-brown beetle with lighter colored wing covers, oblong-ovoid in shape, and ranging in length from one-tenth to one-eighth of an inch. It normally feeds in rotting and decaying fruit and vegetation and in the sap exuding from injured plants. It is quite numerous in cornfields in the South, swarming over the damaged ears and feeding and breeding in the decaying kernels. It is attracted to damp and decaying grain and is not infrequently found in rice mills breeding in accumulations of broken rice. It is often seen in swarms crawling over bags of rice.

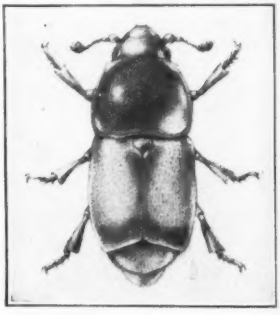

FIGURE 50.—The corn sap beetle, adult. ×15.

A closely related beetle (*Carpophilus humeralis* Murray) that has been introduced from abroad and is becoming more and more abundant is similar in form to the corn sap beetle, but is slightly larger and is uniform, shiny, dark brown all over. Its habits are very similar to those of the preceding species.

CIGARETTE BEETLE

The cigarette beetle (*Lasioderma serricorne* (F.)) is a small, robust, oval, reddish-yellow or brownish-red beetle, with head bent down nearly at right angles to the body, giving the beetle a humped appearance when viewed from the side as shown in figure 51. It varies in size, but is usually about one-tenth of an inch long. It is found in all temperate, subtropical, and tropical regions and infests

tobacco and many other stored products. It breeds in a variety of seeds and may occasionally be found attacking grains left long in storage in original sacks.

The adult beetles live from 2 to 4 weeks, and during this time the females may lay as many as 100 eggs. The developmental period from egg to adult is quite variable but under favorable conditions is from 6 to 8 weeks.

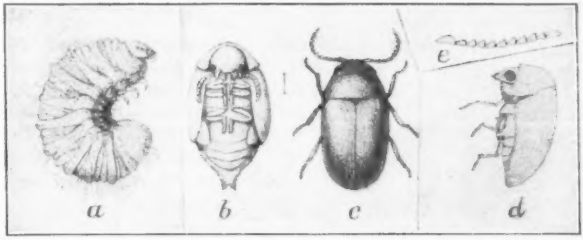

FIGURE 51.—The cigarette beetle: *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle. The beetle is usually about one-tenth of an inch long.

DRUG-STORE WEEVIL

The drug-store weevil (*Stegobium paniceum* (L.)) is very similar in appearance to the cigarette beetle, to which it is closely allied, but differs from it by being more elongate in proportion and in having the wing covers distinctly striated. It is about one-tenth of an inch long, cylindrical, and uniform light brown, its body covered with a fine silky pubescence (fig. 52). The larva, or grub, is very much less

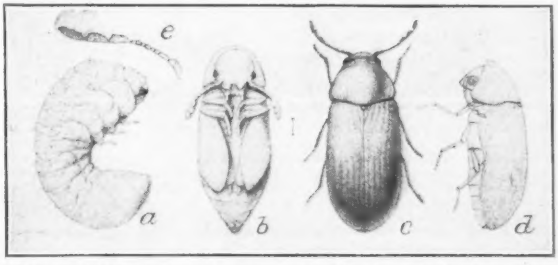

FIGURE 52.—The drug-store weevil is about one-tenth of an inch long. It never attacks grain unless it is stored for long periods unmolested: *a*, Larva; *b*, pupa; *c*, beetle, dorsal view; *d*, beetle, side view; *e*, antenna of beetle.

hairy than that of the cigarette or tobacco beetle. It is known as the drug-store weevil from its habits of feeding on almost all drugs found in pharmacies. It is a very general feeder, attacking a great variety of stored foods, seeds, and other materials, and has been said to "eat anything except cast iron." It is frequently found in storehouses and granaries in all parts of the world.

The eggs of this beetle are laid in almost any dry organic substance. The small white grubs emerging from the eggs tunnel through these substances and when full grown pupate in small cocoons. The entire life cycle may be passed in less than 2 months.

CATORAMA BEETLE

Another beetle closely related to the drug-store weevil and the cigarette beetle and which has similar habits is the catorama beetle (*Catorama* sp.), which is shown in figure 53. It is shiny black and is about one-eighth of an inch long. It is only an occasional pest of stored grain and does not cause serious damage.

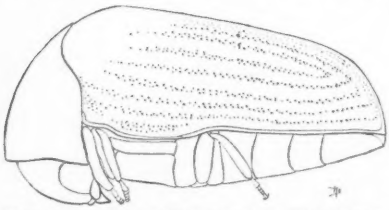

FIGURE 53.—The catorama beetle. This beetle is about one-eighth of an inch long.

BOOKLICE OR PSOCIDS

Grain and grain products are sometimes found to be swarming with minute insects that are scarcely larger than a pinhead. Flour and grain samples appear to be particularly attractive to them. They are known as psocids, or booklice, owing to their resemblance to lice and their occasional presence in books. One of the most abundant of these psocids is the common booklouse (*Troctes divinatorius* (Müll.)) (fig. 54). It is a tiny, pale-grayish or yellowish-white, wingless, soft-bodied louselike insect with a fairly large head, poorly developed eyes, and long, slender antennae. It is about one twenty-fifth of an inch in length. It feeds on a great variety of organic matter, both of plant and animal origin, but is troublesome through its presence rather than for the actual damage it causes.

The females reproduce without mating; in fact, no males are known to exist. As many as 100 eggs may be laid by a single female, and in summer the developmental period from egg to the mature insect is about 3 weeks. The newly hatched young resemble the mature insects in form and general appearance but are smaller and of a lighter color. This insect is widely distributed in North America and Europe.

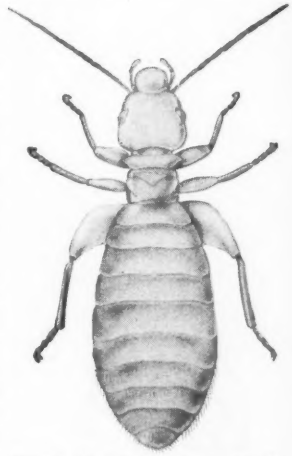

FIGURE 54.—Booklouse or psocid.

A closely related species, *Trogium pulsatorium* (L.), known as the death watch, is similar in appearance and habits and is found under the same circumstances. It may be distinguished from the common booklouse by the fact that it is slightly larger, has a pair of diminutive wing covers, and has well-developed eyes. It also is widely distributed over North America and Europe but is not quite so common or abundant as the preceding species.

SILVERFISH

A rather common insect in mills, warehouses, and dwellings is a glistening, silver or pearly-gray insect known as a silverfish or slicker (*Lepisma saccharina* L.). As shown in figure 55, the pos-

session of three long taillike appendages gives it a characteristic appearance easily recognized. It is cosmopolitan in distribution and feeds on starchy foods of all kinds. It is found particularly in dark, moist, warm situations.

A closely related species, *Thermobia domestica* Pack., known as the firebrat, is found in similar situations and closely resembles the silverfish in appearance and habits. It may be readily differentiated from this species by the fact that instead of having a uniform silvery color, it is pearly white, heavily mottled along the back, with dusky scales that give it a banded appearance. It is probably cosmopolitan in distribution and in some places is more abundant than the silverfish. Development from egg to adult is completed in from 11 to 12 weeks.

FIGURE 55.—Adult silverfish, about two and one-fourth times natural size.

COCKROACHES

Cockroaches are of frequent occurrence in establishments handling cereal products, and everybody is familiar with their appearance. They are particularly abundant in the basements of buildings in dark, moist situations, and when lights are suddenly turned on, it is not uncommon to see the floors of basements almost black with them. The oriental cockroach (*Blatta orientalis* L.) (fig. 56) is probably the commonest species found in flour mills and food establishments in North America. It is a large roach, dark brown or black, measuring when full-grown about an inch in length. The females are unique in that they have no wings—merely short wing pads. The males have fully developed wings.

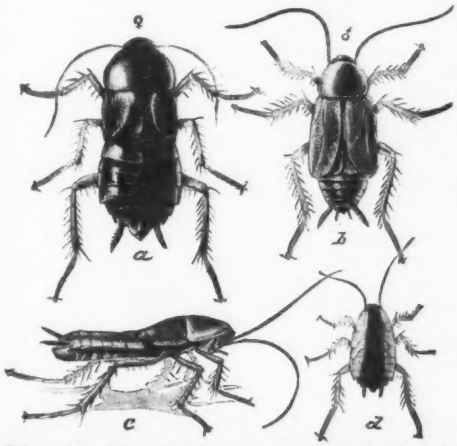

FIGURE 56.—The oriental cockroach: *a*, Female; *b*, male; *c*, side view of female; *d*, half-grown specimen. All natural size.

A closely related species, *Periplaneta americana* (L.), known as the American cockroach, is also quite abundant and in many flour mills in the Southwestern and Midwestern States is the predominant form. It is even larger than the oriental cockroach and frequently is 1½ inches

in length. It is bright sienna brown except for the pronotum, which is brownish yellow and encloses the characteristic, irregular-shaped, reddish-brown double spot in the center. It is shown in figure 57.

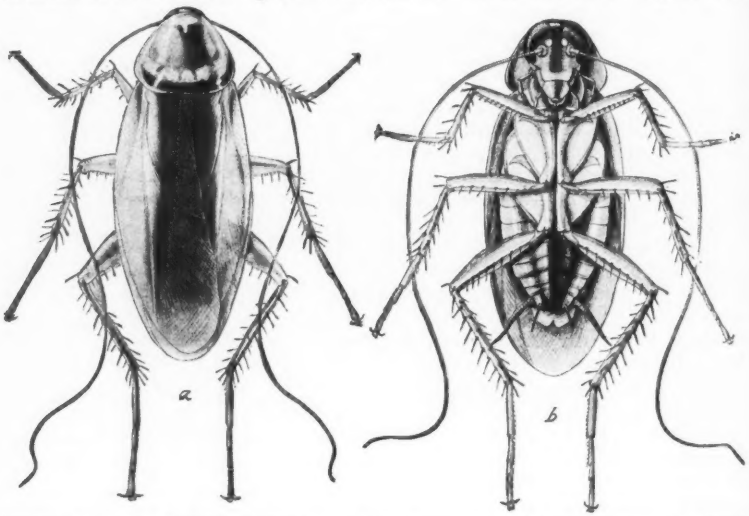

FIGURE 57.—The American cockroach: *a*, View from above; *b*, from beneath. Enlarged one-third.

FLOUR OR GRAIN MITES

The flour or grain mites are pale, grayish-white, smooth, soft-bodied creatures microscopic in size, and provided with numerous long hairs on the legs and back, as shown in figure 58. Mites are not true insects, as the adults have eight legs and the body is indistinctly divided into two parts. They have no wings. The flour or grain mites are much smaller than the booklice, being usually less than one-fiftieth of an inch in length. They are often found in stored grain and occasionally increase with such rapidity that the grain seems to be fairly alive with them. During heavy infestations their cast skins and dead bodies accumulate in fluffy light-brown masses beneath the sacks of grain. If these accumulations are on a warehouse floor, they roll up into piles, which are blown about with each gust of wind. No other group of pests in grain will produce these masses. When present in large numbers, they promote sweating, impart a disagreeable odor to the grain, and may cause damage by their feeding. Fortunately the mites that attack grain are themselves preyed upon by predacious mites, which usually become abundant enough to kill the grain mites in a comparatively short time. If they do not, the screening and fanning of grain will usually reduce mite infestations to a point where no injury takes place.

The most injurious species of mite found in flour, grain, and cereal products in North America is *Tyroglyphus farinae* (Deg.), which is popularly known as the flour mite, common forage mite, or grain

mite. It multiplies with great rapidily under favorable conditions and may complete its life cycle from egg to mature mite in a little over 2 weeks.

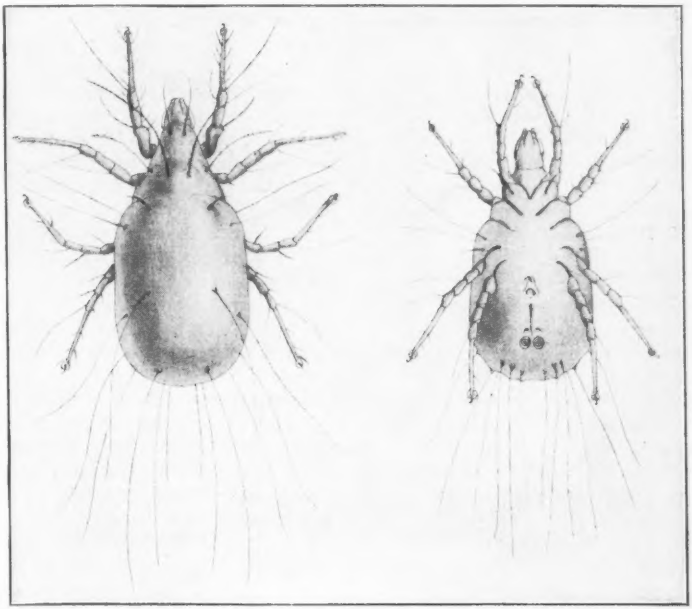

FIGURE 58.—Grain mites.

Another very common species, *T. longior* Gerv., also known as the flour mite, but sometimes as the cheese mite, is similar in appearance and habits to the preceding species.

PARASITES OF GRAIN PESTS

Grain in bulk is sometimes seen swarming with small wasplike creatures of the size and appearance shown in figure 59. Similar insects may also be seen on the windows of flour mills and other establishments where cereal products are handled. These insects are not harmful but beneficial in that they attack and destroy the insects that infect grain and grain products.

The small parasite shown resting on the kernel of wheat in figure 59 is the adult of *Aplastomorpha calandrae* (How.), the most important parasite of the rice and granary weevils. The female wasp

FIGURE 59.—*Aplastomorpha calandrae*, a hymenopterous parasite of grain pests resting upon a kernel of wheat.

is able to detect the presence of the grain weevil grub hidden from sight within the grain and paralyzes it with a few thrusts of the ovipositor. A single egg is then deposited on the exterior of the grub or in close proximity to it. The egg hatches, and the parasite grub feeds on the paralyzed weevil grub, thus destroying it. The developmental period from egg to adult is about 2 weeks. A single female parasitic wasp has been observed to lay as many as 283 eggs, but the help usually comes too late to prevent damage to the crop.

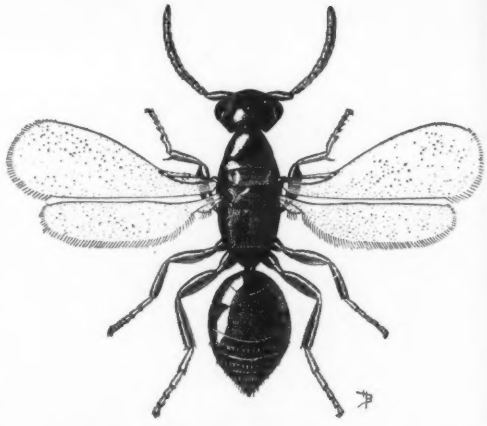

FIGURE 60.—*Cephalonomia tarsalis*, adult. × 21.

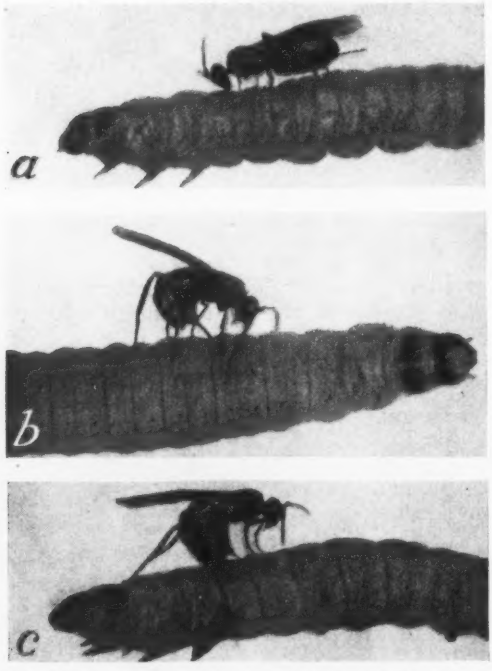

FIGURE 61.—Female of *Microbracon hebetor* in three poses: *a*, Feeding on the body fluids of a larva of the Mediterranean flour moth and showing the short, straight ovipositor protruding behind; *b*, the parasite in the position assumed in puncturing the body of the larva preparatory to laying an egg; *c*, the parasite with the ovipositor well inserted in the larva and about to lay the egg.

Another fairly common parasite of the grain beetles is shown in figure 60. This parasite, *Cephalonomia tarsalis* (Ashm.), has habits quite similar to those of the preceding species.

The adult of *Microbracon hebetor* (Say) attacking larvae of one of the meal or flour moths is illustrated in figure 61. This little wasp is one of the most important parasites of these moths. It first paralyzes the flour moth caterpillar by stinging it several times.

Then it places several eggs on the paralyzed caterpillar. These eggs hatch into small, white, footless, grublike larvae that suck the body

FIGURE 62.—*Idechthis canescens*. × 8.

juices of the caterpillar. Under favorable circumstances this parasite completes its development from egg to adult wasp again in less than 2 weeks.

Another beneficial wasp that is of even greater importance as a parasite of the flour and meal moths is *Idechthis canescens* (Grav.). This slender wasp (fig. 62) has a reddish-brown abdomen, with head and thorax black and legs a reddish brown to yellow.

The habits of this parasite are somewhat different from those of the preceding species. The adult wasp deposits its eggs inside the body of the flour moth caterpillar and the entire development of the parasitic larva, until just before pupation, takes place within the host. The host caterpillar is not paralyzed and continues feeding until the parasitic larva has become nearly full grown. The developmental period from egg to adult requires between 3 and 4 weeks.

FIGURE 63.—Larva of a kind of fly that preys upon grain beetles and mites. This white threadlike worm sometimes attains a length of about three-fourths of an inch.

Grain dealers and millers not infrequently find a small, threadlike, white worm (fig. 63), about three-fourths of an inch long, in accumulations of flour or grain dust. This is the larva of a small black fly, *Scenopinus fenestralis* (L.) (fig. 64), known as the windowpane fly from its frequenting the windows of mills and similar establishments. This white worm does not injure grain or cereal products but is a predator on other insects found in mills and warehouses. *S. glabrifrons* Meig. is a closely allied species, also known as a windowpane fly.

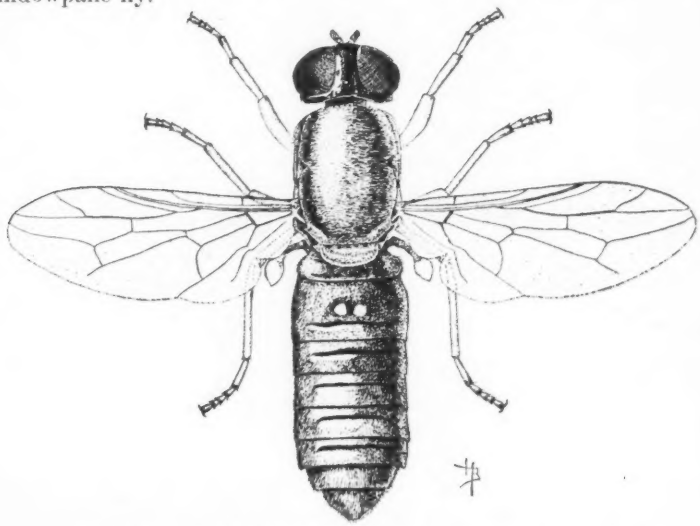

FIGURE 64.—Adult of the windowpane fly (*Scenopinus fenestralis*).

HOW GRAIN BECOMES INFESTED

Grain may become infested in a number of ways. In many grain-growing regions infestation starts in the field before the crops are harvested. This is, of course, particularly true in the South, where the rice weevil and other insects are abundant in the field at harvest time, and in the soft red winter wheat region of the Eastern States, where the Angoumois grain moth is frequently extremely destructive. In the more northern States that experience severe winters field infestation is a negligible factor.

In addition to field infestation, which may or may not be important, depending on the region or the season, there are several other sources of infestation of stored grain that are of considerable importance.

In all regions it is customary to store grain year after year in the same bins. If these bins are made of wood, cracks and crevices become filled with dust and broken grain and afford places of concealment for many insects. Insects such as the cadelle burrow into the wooden sides or floors to pupate, and later emerge in enormous

numbers. Grain bins are not always properly cleaned, hence fresh grain stored in them quickly becomes infested.

The custom of storing bran, shorts, and other milled feeds in or near the granary is another serious source of infestation, since these products are invariably infested. Many bins, too, are located in barns that normally contain supplies of products in which insects breed.

Temporary storage of grain in country or crib elevators frequently adds to the danger of infestation. Such storage is difficult to keep free from infestation, and clean grain often becomes contaminated by infested grain arriving at the same place.

Grain may also become infested in railroad boxcars in which it is being transported to terminal elevators. Many grain-infesting insects live in the dust and waste grain that accumulate in cracks in the floors or woodwork and in accumulations behind the linings of the cars.

Storage in warehouses and elevators already containing infested grain also results in contamination through the spread by flight or by crawling of insects from the infested to the clean grain.

Uninfested grain should not be placed for shipment in sacks previously used for grain storage, for, as shown in figure 24, these old sacks often harbor insects unless they have been sterilized by heat or fumigation. Certain extensive and costly infestations have been traced directly to the use of second-hand infested and untreated grain sacks.

Grain stored in the open or in poorly constructed cribs or bins may become infested by insects flying in from outside.

HOW TO PREVENT PRIMARY INFESTATION

Infestation of small grain in the field cannot be entirely prevented, but by proper precautions it can be reduced to a minimum. If the grain is cut as soon as ripe, threshed as soon as dry, and then placed in storage in clean, deep bins, the damage from this source will be very slight. It is when the grain is left in the field long after it is ripe that serious infestation results, for the insects increase in one or two generations to enormous numbers. In the case of corn in the field, those ears that are damaged by earworms or other agencies and have kernels exposed through poor shuck development are subject to the attack of grain insects. Farmers should therefore grow a variety of corn that develops a long, tight husk.

Newly harvested small grains should not be stored unthreshed for any length of time, as in this condition they are very susceptible to infestation. If promptly threshed and stored in deep, clean bins, only a thin layer on top of the bin is likely to become infested. Corn may be stored in the shuck if the husk is long and tight and fully covers the tip, but all ears with loose, broken, short, or damaged husks should be shucked and stored separately.

Clean grain should never be stored in old bins, granaries, or storehouses until they have been thoroughly cleaned and freed from the accumulations of waste grain and other materials harboring grain insects. Timbers in bins, granaries, or holds of ships that have become infested with grain insects should be destroyed or treated

before being used again. Steel or concrete bins are highly desirable owing to the ease with which they are cleaned.

Bran, shorts, or milled feeds of any kind should not be stored in or near granaries. Bags of all kinds that have previously held grain should not be allowed in granaries or warehouses or be refilled until they have been sterilized by heat or otherwise freed from insects. The use of tight cribs will keep the grain free from infestation by insects that might fly in from the outside.

Information regarding the treatment of infested grains is contained in other publications of the Department of Agriculture, copies of which can be obtained by writing to the Bureau of Entomology and Plant Quarantine.

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